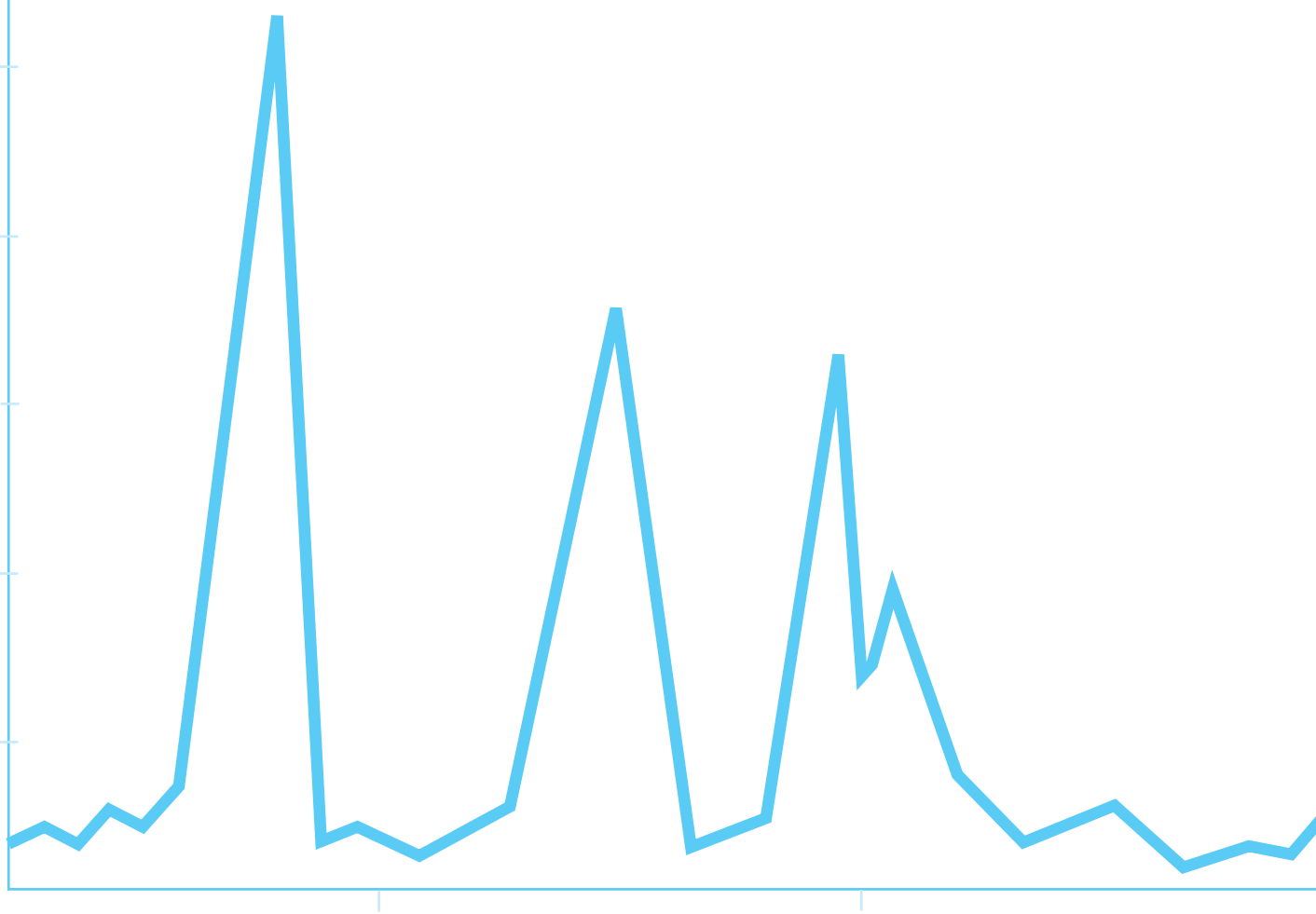


# API 2000™ LC/MS/MS System

## Service Manual

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June 2005



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# 1 Overview

---

## 1.1 About This Manual

This service manual contains information required to maintain the API 2000 instrument. It contains detailed descriptions of the system components, as well as preventive maintenance and corrective maintenance procedures.

The service manual is part of a set of manuals that also includes the *API 2000 Operator's Manual* and the *API 2000 Qualified Operator's Service Manual*. Other related documents include the *API 2000 LC/MS/MS Triple Quadrupole Products Site Guide, Instrument and Operations Qualification Manual*, the *TUNE Software Manual*, the *Sample Control Software Manual* and the *MultiView Manual*.

Within the scope of this manual, the following conventions are used:



---

|                |                                                                                               |
|----------------|-----------------------------------------------------------------------------------------------|
| <b>WARNING</b> | <i>Indicates an operation that may cause personal injury if precautions are not followed.</i> |
|----------------|-----------------------------------------------------------------------------------------------|

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|                |                                                                                                        |
|----------------|--------------------------------------------------------------------------------------------------------|
| <b>Caution</b> | <i>Indicates an operation that may cause damage to the instrument if precautions are not followed.</i> |
|----------------|--------------------------------------------------------------------------------------------------------|

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|             |                                                                          |
|-------------|--------------------------------------------------------------------------|
| <b>Note</b> | <i>Emphasizes significant information in a procedure or description.</i> |
|-------------|--------------------------------------------------------------------------|

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## 1.2 International Standards Certifications

This instrument and its components have been certified by the following international agencies. Applicable labels for these qualifications have been attached to various components of the instruments.

### **FCC**

The API 2000 comply with FCC Part 15, Subpart B, Class A.

---

|             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|-------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>Note</i> | <i>This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at the user's own expense.</i> |
|-------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

---

### **CISPR**

The API 3000 complies with Class A of CISPR publication 22 (1993)/British Standard BSI EN 55022 (1987).

### **IEC**

The API 3000 is certified to comply with the 'Low Voltage Directive (73/23/EEC & 93/68/EEC)', standard EN61010-1 and the 'EMC Directive (89/336/EEC & 93/68/EEC)', and its standards EN50081-1 & EN50082-1

### **CE**

Certificate of CE compliance is included with the instrument.

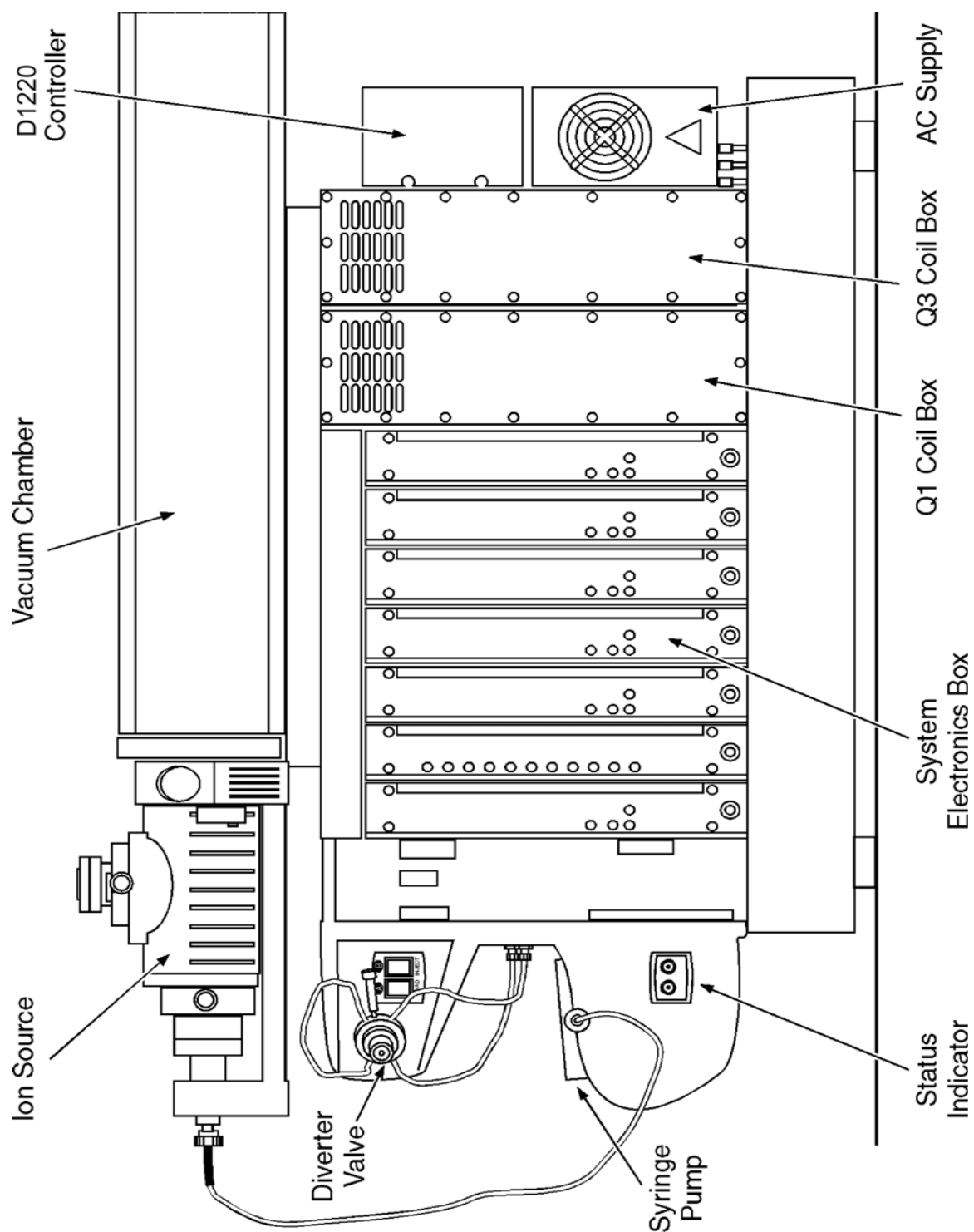


Figure 1-1. API 2000 System - Front

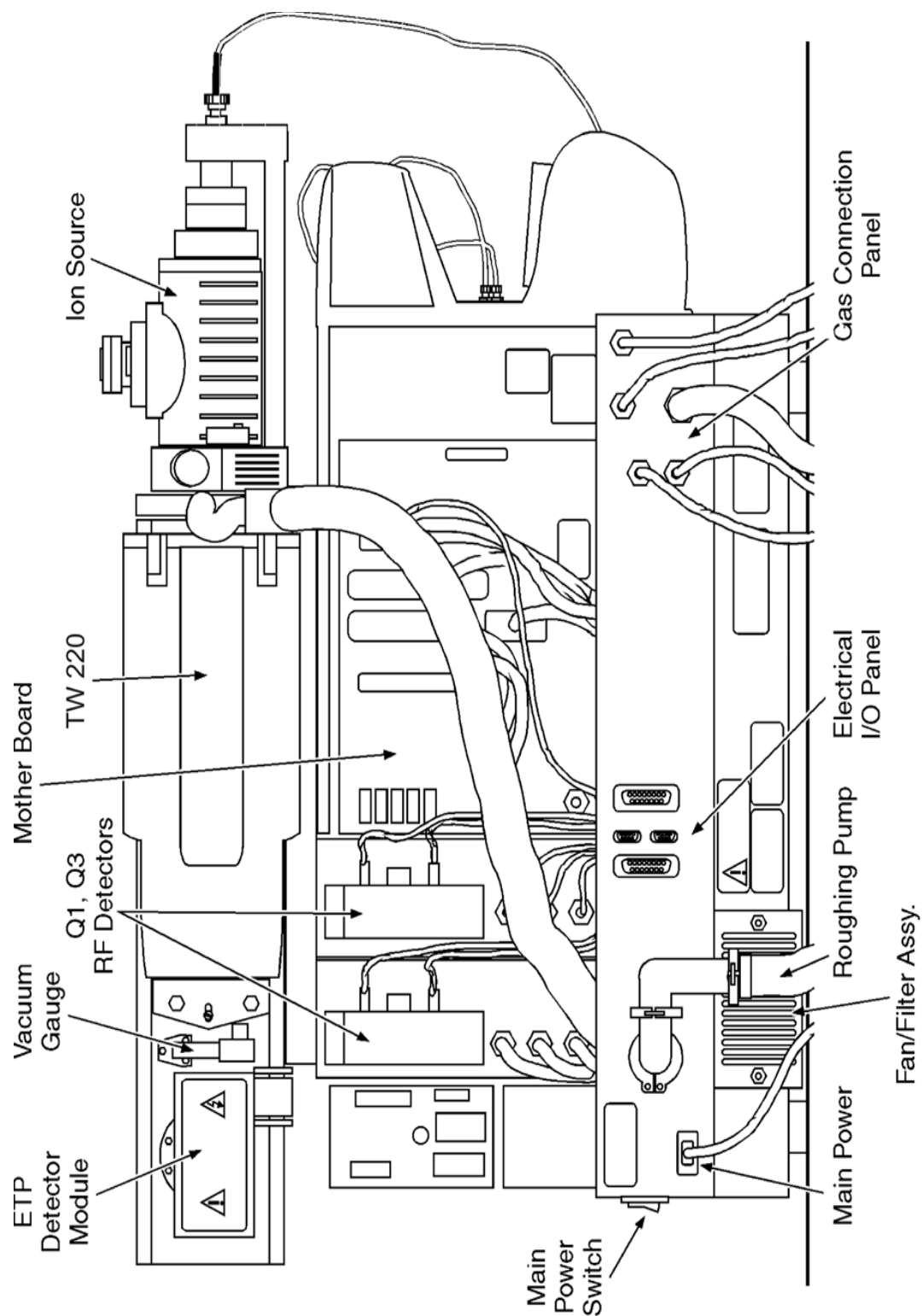


Figure 1-2. API 2000 System - Rear

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The rest of this manual is divided into service procedures based on instrument assemblies.

All procedures should be strictly followed to ensure safety in the servicing of this instrument.



---

**WARNING**     *All standard safety precautions regarding high voltages, vacuum systems, and electrostatic discharge must be followed to prevent personal injury or damage to the instrument.*

---



---

**WARNING**     *Verify with the operator that no biohazardous materials were run through the instrument. If these materials have been used, ask the operator to use the proper cleaning methods before maintenance.*

---

---

## 1.3 Servicing the API 2000 Chassis

### 1.3.1 Chassis

The chassis is the main physical support for the instrument components, and the main path for grounding the instrument's electrical components. All the electrical components are grounded to the chassis. The chassis is connected directly to the AC power supply ground circuit.

The chassis base is a steel tubular frame on which the API 2000 main console is assembled. The vacuum chamber that houses the mass filter rail and supports both the vacuum interface and the Ion Source, is fastened to the chassis base.

All connections to external sources are made through bulkheads attached to the chassis. The external power supply, IEEE connection to the host computer, the AUX I/O and the serial port connections are made through the back panel. See the table below.

**Table 1-1. API 2000 Connection Panel Locations**

| Panel            | Location                             |
|------------------|--------------------------------------|
| I/O Panel        | rear of the chassis, centre          |
| Gas Supply Panel | rear of the chassis, right hand side |
| Ion Source Panel | chassis front, left side             |
| Main Power       | rear of the chassis, right side      |

---

### 1.3.2 I/O Panel

The external power supply, the IEEE-488 connection to the Applications Computer, the AUX I/O and the serial port connections are made through the I/O Panel on the rear centre of the chassis as shown below.

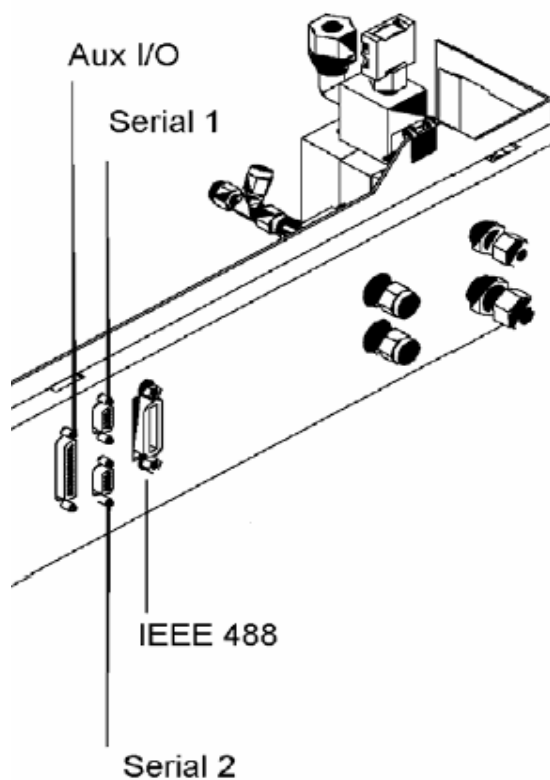


Figure 1-3. I/O Panel

### 1.3.3 Gas Connection Panel

The vacuum lines to the Backing Pump are connected through the Gas Connection Panel on the rear right-hand corner of the chassis. The panel also houses on the left-hand side, the GAS 1/GAS 2 and Curtain Gas supply connections and the external connections for the Source Exhaust System. It also shows the connections for the Exhaust and Valve Waste.

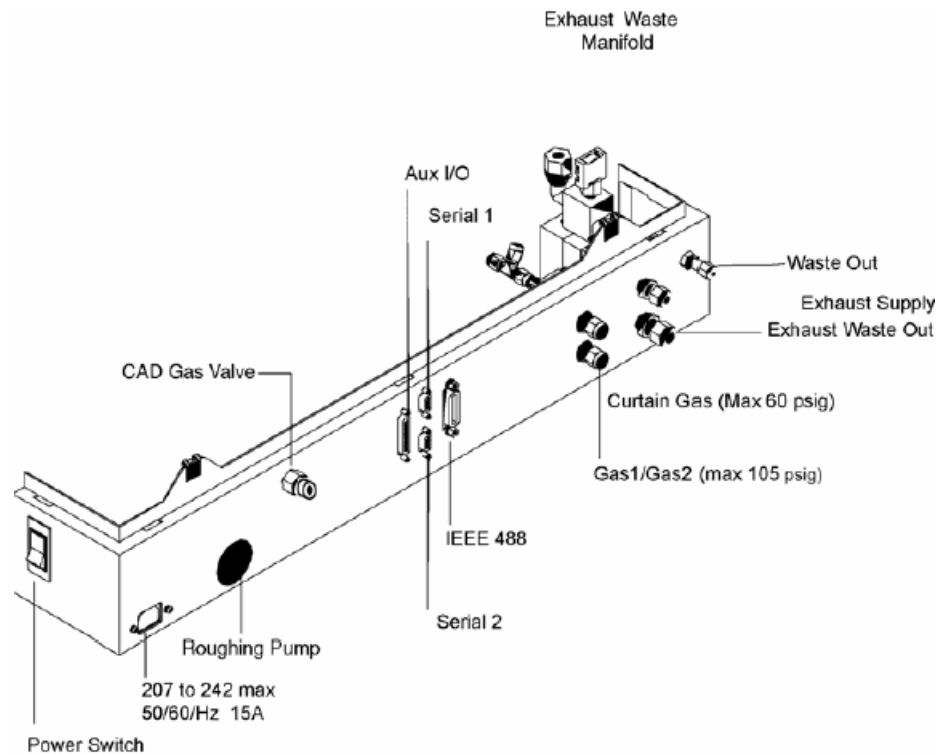


Figure 1-4. Gas Connection Panel

---

### 1.3.4 Interface Assembly

The Interface Assembly is located at the left-hand side of the instrument. It is connected to the vacuum chamber and supports connections for Gas 1, Gas 2, and Gas 3 and the electrical connections.

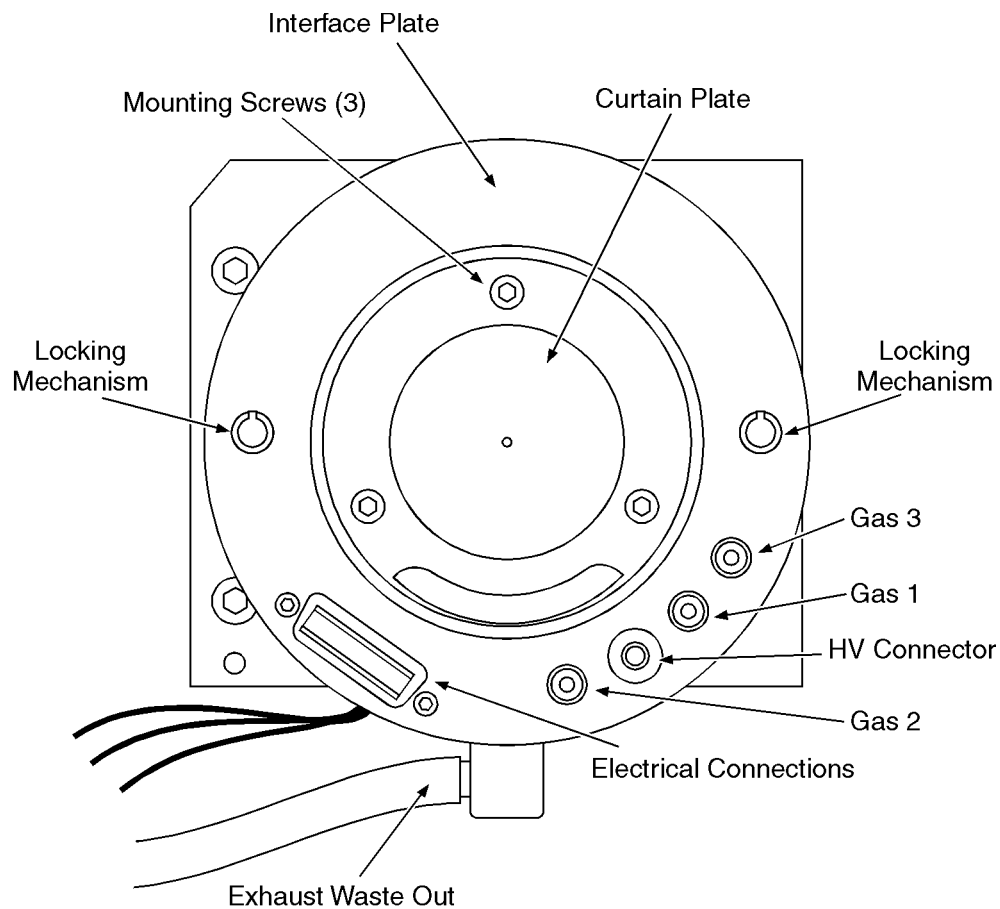


**Figure 1-5. Interface Assembly**

---

## 1.4 Servicing the API 2000 Covers

This procedure should be followed before performing any maintenance on the instrument to minimize the potential for exposure to the instrument's high-operating voltages.

When shutting down the instrument, care must be taken to prevent the rotary vane pump's exhaust from being drawn into the vacuum chamber via the turbo pump exhaust ports. The likelihood of this happening is reduced because the rotary vane pump has a valve that isolates the pump exhaust from the pump intake when the pump is shut off or fails.

### Shutting down the API 2000 instrument

1. Complete any ongoing scans or select the **abort scan** command from the TUNE or Sample Control application.

---

|             |                                                                                                                                                               |
|-------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>Note</i> | <i>Windows NT and MAC users should choose <b>Stop Sample</b> from the <b>Acquire</b> menu. The queue stops after the current scan in the selected sample.</i> |
|-------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|

---

2. Shut off the sample flow to the Ion Source.

---

|                |                                                                                |
|----------------|--------------------------------------------------------------------------------|
| <i>Caution</i> | <i>The sample flow must be turned off before shutting down the instrument.</i> |
|----------------|--------------------------------------------------------------------------------|

---

3. Perform an **overnight quit** from the TUNE or Sample Control application to disengage the Data Acquisition Computer from the instrument.

---

|             |                                                                                            |
|-------------|--------------------------------------------------------------------------------------------|
| <i>Note</i> | <i>Windows NT and MAC users should choose <b>Standby</b> from the <b>Acquire</b> menu.</i> |
|-------------|--------------------------------------------------------------------------------------------|

---

4. Shut off the Main Power switch to the instrument from the bulkhead at the back right corner of the chassis.

---

|                |                                                                                                                                                                                                                                              |
|----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>Caution</i> | <i>If the instrument is going to be shut down for any length of time, it is recommended that the vacuum chamber be vented to prevent the Rotary Vane Pump exhaust from being sucked back into the vacuum chamber (follow steps 5 and 6).</i> |
|----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

---

---

|                |                                                                                                                                                                                                                                                                           |
|----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Caution</b> | <b><i>If the vacuum chamber is not going to be vented while the instrument is shut down, it is recommended that the Backing Pumps remain turned on to prevent the rotary vane pump's exhaust from being sucked back into the vacuum chamber (skip steps 5 and 6).</i></b> |
|----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

---

5. Shut off the backing pump. This pump is located outside the main console. The power switch is located beside the power supply input attachment.
6. To vent the vacuum chamber, remove the venting screw with a 5mm socket wrench from the front of the chamber.

### **Powering Up the API 2000 Instrument**

1. Replace the venting screw on the front of the vacuum chamber and tighten if the instrument was vented.
2. Replace the instrument covers.
3. Switch on the Backing Pump, if it was turned off.

---

|             |                                                                                                                                         |
|-------------|-----------------------------------------------------------------------------------------------------------------------------------------|
| <b>Note</b> | <i>The pump has its own power toggle switch and must be turned on manually. It is not controlled remotely by the System Controller.</i> |
|-------------|-----------------------------------------------------------------------------------------------------------------------------------------|

---

4. Ensure that the Curtain Gas supply is flowing to the instrument. The pressure should be regulated to 60 psig.
5. Ensure that the 207V to 242V main power supply is plugged into the electrical connections panel.
6. Turn on the main power switch.
7. Ensure that the Graphical Purpose Interface Bus (GPIB) box is turned on and is connected to both the API 2000 instrument and the Applications Computer.
8. Turn on the Applications Computer.

---

## 1.5 Instrument Covers

There are four covers that enclose the operating modules of the API 2000. The covers can be opened to allow access to the instrument's component modules, the System Electronics Box, and the operational parameter check points. The covers are designed to prevent access to the instrument when high-operating voltages are engaged.

### 1.5.1 Front Cover

The front cover is the main cover that must be removed before you can open the remaining covers.

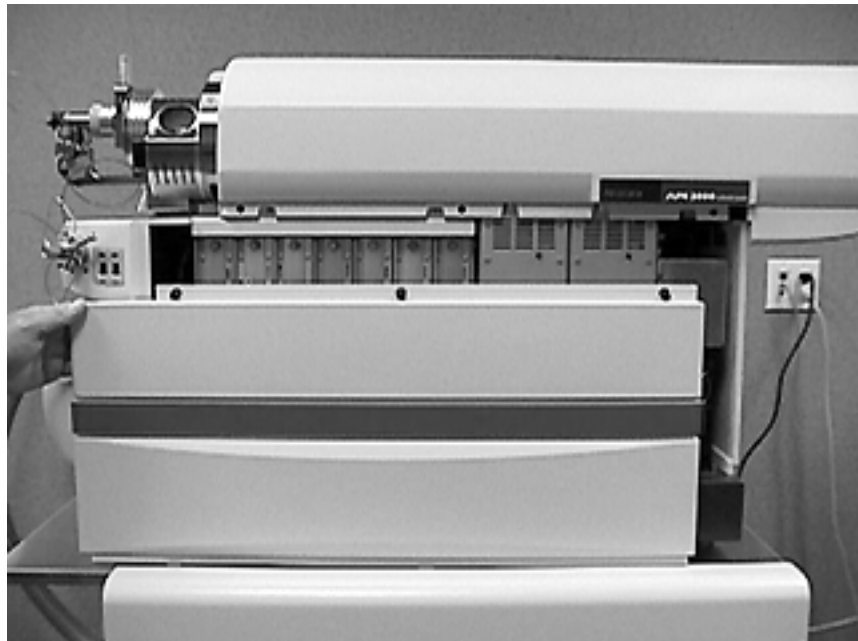


**Figure 1-6. API 2000 - Front Cover**

Opening the front cover exposes the main components of the API 2000, including many of the system test points. The cover is secured at the top by three screws that are mounted on top of the card cage and coil box. It is inserted to the chassis on the bottom with three tabs. It is not hinged to the chassis and must be removed to access the front of the API 2000.

1. Shut off the instrument.
2. Remove the Ion Source.



---

**WARNING**     *Do not open the API 2000 covers unless the Ion Source is removed first. Failure to follow this sequence will expose the operator to the operating voltages.*

---

3. Unscrew the three captured bolts that secure the Front Cover to the instrument.
4. Grasp the top corners of the Front Cover and gently pull and lift the cover to remove it.

### 1.5.2 Top Cover



Figure 1-7. API 2000 - Top Cover

1. Remove the Front Cover.



---

**WARNING**     *Do not open the API 2000 covers unless the Ion Source is removed first. Failure to follow this sequence will expose the operator to the operating voltages.*

---

2. Unscrew the two captured bolts that secure the top cover to the back of the instrument.
3. Tilt the front end of the cover up and gently pull towards the rear. Lift the cover to remove it.

---

### 1.5.3 Back Cover

The back cover encloses most of the systems cabling. It is not hinged and must be removed to access the back of the API 2000.

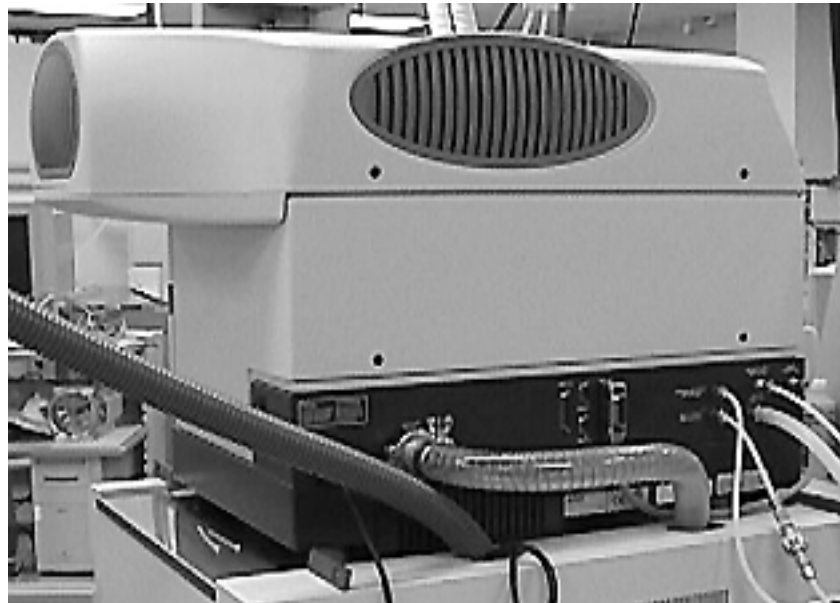


Figure 1-8. API 2000 Back Cover

1. Remove the front cover.
2. Remove the top cover.



---

**WARNING**     *Do not open the API 2000 covers unless the Ion Source is removed first. Failure to follow this sequence will expose the operator to the operating voltages.*

---

3. Unscrew the two captured bolts that secure the back cover to the back of the instrument.
4. Gently lift the cover to remove it.

### 1.5.4 Power Distribution Cover

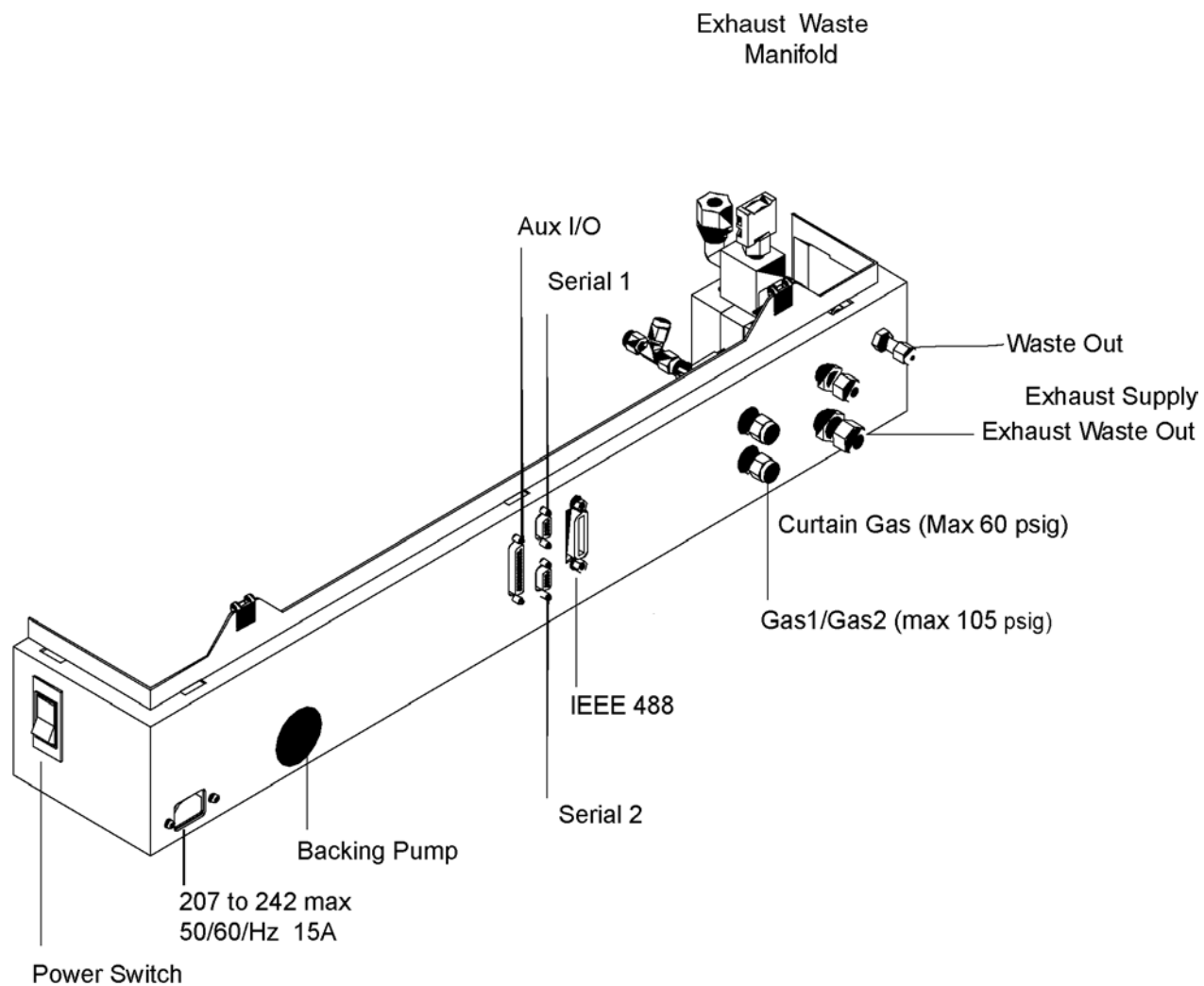


Figure 1-9. API 2000 Power Distribution Cover



**WARNING** *There are no operator serviceable items located behind the power distribution cover.*

---

## 1.6 Servicing the Filters

### Removing and Replacing the Handles

1. Shut down the instrument.
2. Unscrew and remove the three bolts that connect the handles at each end of the instrument.
3. To replace the handles, reattach them at both ends of the chassis.

### Removing and Replacing the Card Cage Blower Filter

A cooling fan housed inside the instrument chassis blows air over the circuit boards housed in the system electronics box and the turbo pump that is attached to the vacuum chamber. An air filter, which filters the cooling fan's intake air, is mounted to the chassis in front of the fan.



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|                |                                                                                                                                                                                                                                                        |
|----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>WARNING</b> | <b>BIOHAZARDOUS MATERIAL</b> <i>Do not dispose of system components or subassemblies, including computer parts, in municipal waste. Dispose of replaced components and instruments according to established waste electrical equipment procedures.</i> |
|----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

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|                |                                                                                                                                                                |
|----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Caution</b> | <i>This filter should be replaced every three months of operation or when it becomes dirty. Use correct replacement filter or the instrument may burn out.</i> |
|----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------|

---

The card cage blower filter can be replaced easily without opening or removing any of the instrument's covers. The filter is accessed via a filter cover located on the chassis in the back corner.

---

|                |                                                                                                                                               |
|----------------|-----------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Caution</b> | <i>The API 2000 instrument must be turned off before removing the filter cover, otherwise the filter can be pulled into the fan assembly.</i> |
|----------------|-----------------------------------------------------------------------------------------------------------------------------------------------|

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1. Shut off the Instrument.
2. With a flat head screwdriver, loosen the screws that secure the filter cover plate.
3. Remove the filter cover and the filter from the frame.

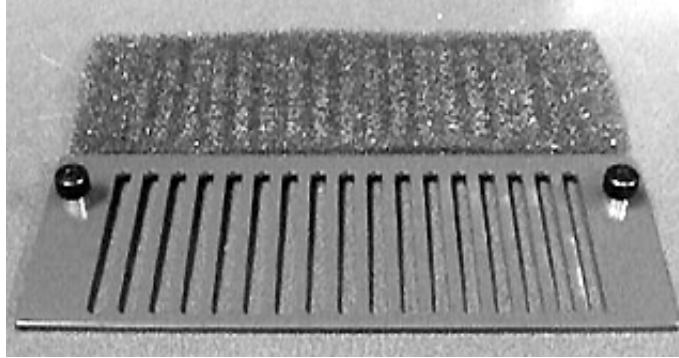


**Figure 1-10. Cooling Fan Filter and Cover**

4. Place the replacement filter on the filter cover plate.
5. Mount the filter cover and filter to the chassis by tightening the two screws you loosened in step 2.
6. Turn on the instrument.



## 2 TurboIonSpray and Ion Source

### 2.1 Overview

TurboIonSpray is an atmospheric pressure ion source in which pre-formed ions in a solution are emitted into the gas phase without applying heat. In this way, quasi-molecular ions can be generated from very labile and high molecular weight compounds with no thermal degradation. It is the technique by which a liquid sample is pumped by a liquid chromatograph (LC) pump or syringe drive through a sprayer tube that is maintained at a high voltage, and is nebulized into the Ion Source creating a mist of highly charged droplets (see the figure below). Once inside the Ion Source, the droplets evaporate causing the ions to enter the gas phase by a low energy process called Ion Evaporation.

The use of an orthogonal heated gas extends the rugged and versatile technique of TurboIonSpray to accept higher flow rate with improved sensitivity. TurboIonSpray will accept flows from 5 to 1000  $\mu\text{L}/\text{min}$  of solvent compositions from 100% aqueous to 100% organic, such as acetonitrile, without splitting. This allows the use of 1mm, 2mm, and 4.6mm analytical columns with or without splitting.

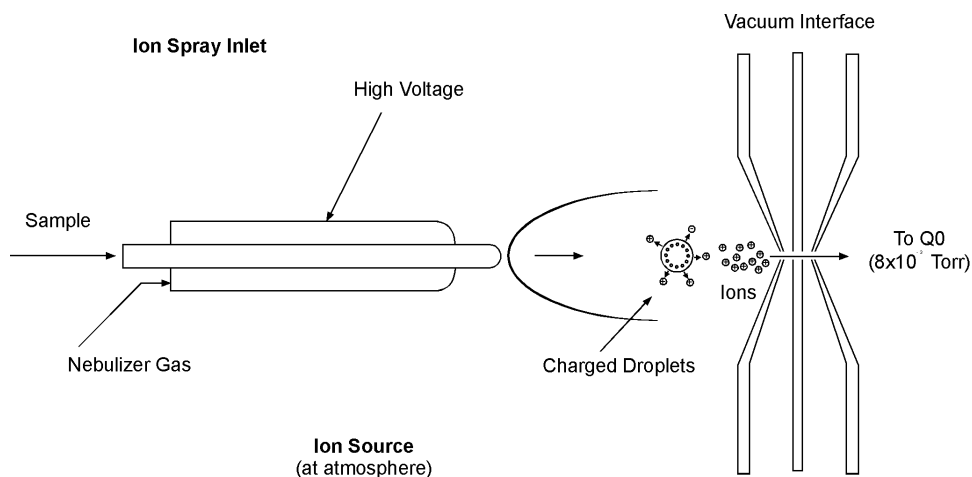


**Figure 2-1. Illustration of IonSpray and Ion Source**

The heater probe directs a jet of heated dry gas (up to a maximum of 500°C) at the mist produced by the sprayer. The gas is sprayed across the orifice at an angle of approximately 45° with respect to the Curtain Plate. The liquid spray emerging from the TurboIonSpray is directed at an angle of about 45° from the opposite direction (or 135°). The TurboIonSpray effluent and the heated dry gas intersect at an angle of approximately 90°

---

near the orifice. This interaction helps focus the TurbolonSpray stream and increases the rate of droplet evaporation resulting in an increased ion signal.

TurbolonSpray is ideally suited for LC/MS/MS quantitative analyses. The sensitivity increases that are achieved with this technique are both flow rate and analyte dependent. In the conventional TurbolonSpray, source sensitivity decreases with increased flow rate, while the heated TurbolonSpray process increases ionization efficiency, especially at the higher flow rates. This results in improved sensitivity. Sensitivity is compound dependent and compounds of extremely high polarity and low surface activity usually show the greatest sensitivity increases. The TurbolonSpray technique is mild enough to be used with labile compounds such as peptides, proteins, and thermally labile pharmaceuticals.

---

|             |                                                                                                                                                                                                                                                                                                                                         |
|-------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>Note</i> | <i>The difference between conventional IonSpray and TurbolonSpray is that in the TurbolonSpray, the ionization of the sample is achieved with additional heater gas delivered to aid in the desolvation of the spray. Typically the TurbolonSpray is used at higher flow rates (greater than or equal to 40 <math>\mu</math>L/min).</i> |
|-------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

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## 2.2 TurbolonSpray Theory

This section describes the theory of TurbolonSpray, including the formation of charged droplets and ion evaporation mechanism.

### 2.2.1 Droplet Generation and Charging



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**WARNING**     *All during normal operation, high voltages exist in the TurbolonSpray inlet. Do not operate the instrument without the viewing glass in place in the TurbolonSpray inlet casing.*

---

A high-velocity flow of nebulizer gas shears droplets from the liquid sample stream in the TurbolonSpray inlet. Using the variable high voltage applied to the sprayer, a net charge is applied to each droplet and aids in the droplet dispersion. Ions of a single polarity are preferentially drawn into the droplets by the high voltage as they are separated from the liquid stream. The separation, however, is incomplete, therefore each droplet contains many ions of both polarities. Ions of one polarity are predominant in each droplet, and the difference between the number of positively or negatively-charged ions results in the net charge. Only the excess ions of the predominant polarity are available for ion evaporation, and only a fraction of these actually evaporate.

The polarity and concentration of excess ions depends on the magnitude and polarity of the high-voltage potential applied to the sprayer tip. For example, when a sample contains arginine in water/acetonitrile, and a positive potential is applied to the sprayer, the excess positive ions will be  $H^+$  and  $MH^+$  arginine.

TurbolonSpray can generate multiple-charged ions from compounds that have multiple charge sites, such as peptides and oligonucleotides. This is useful when observing high-molecular weight species, where the multiple charges produce ions of a mass-to-charge ( $m/z$ ) value within the mass range of the instrument. This allows routine molecular weight determinations of compounds in the kilodalton (kDa) range.

### 2.2.2 Ion Evaporation

Each charged droplet contains solvent and both positive and negative ions, with ions of one predominant polarity. A simple view of the droplet as a conducting medium suggests that excess charges reside at the droplet's surface (see the next figure). As the solvent evaporates, the electrical field at the surface of the droplet increases due to the decreasing radius of the droplet.

If the droplet contains excess ions, and evaporates enough, a critical field is reached at which ions are emitted from the surface. Eventually, all of the solvents will evaporate from the droplet, leaving a dry particle consisting of the non-volatile components of the sample solution.

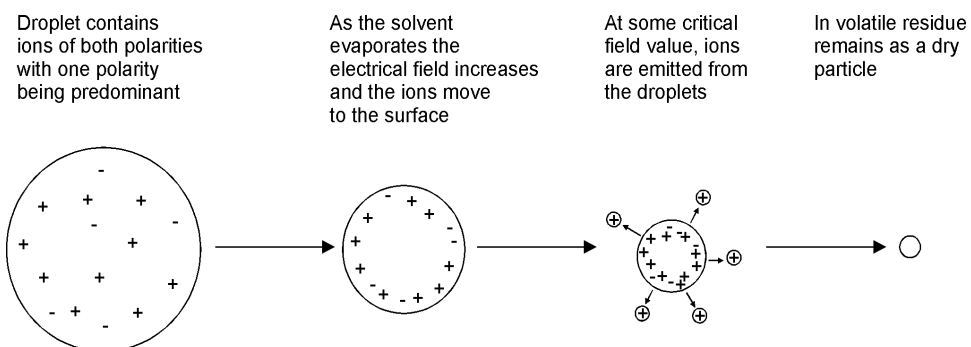


**Figure 2-2. Ion Evaporation**

Only compounds that ionize in the liquid solvent can be generated as gas phase ions in the Ion Source. The efficiency and rate of ion generation depends on the solvation energies of the specific ions. Ions with lower solvation energies are more likely to evaporate than ions with higher solvation energies.

Given that the solvation energies for most organic molecules are unknown, the sensitivities of any given organic ion to ion evaporation is difficult to predict. The importance of solvation energy is shown by the observation that surfactants that concentrate at the surface of a liquid tend to very sensitively detected.

### 2.2.3 Ion Source

"Ion Source" refers to the area where sample ions are generated. In the context of this manual, it refers to the round chamber that houses the sample inlet. The Ion Source is located at the left-most end of the main console as viewed from the front of the instrument (see the TurbolonSpray Inlet and Ion Source figure).

The Ion Source housing mounts to the front end of the Vacuum Chamber, and is held in position by two locking arms. A Plexiglass window on the side of the housing allow you to observe the TurbolonSpray Inlet. The Ion Source and housing can be quickly and easily removed without tools to allow you access to the Vacuum Interface.

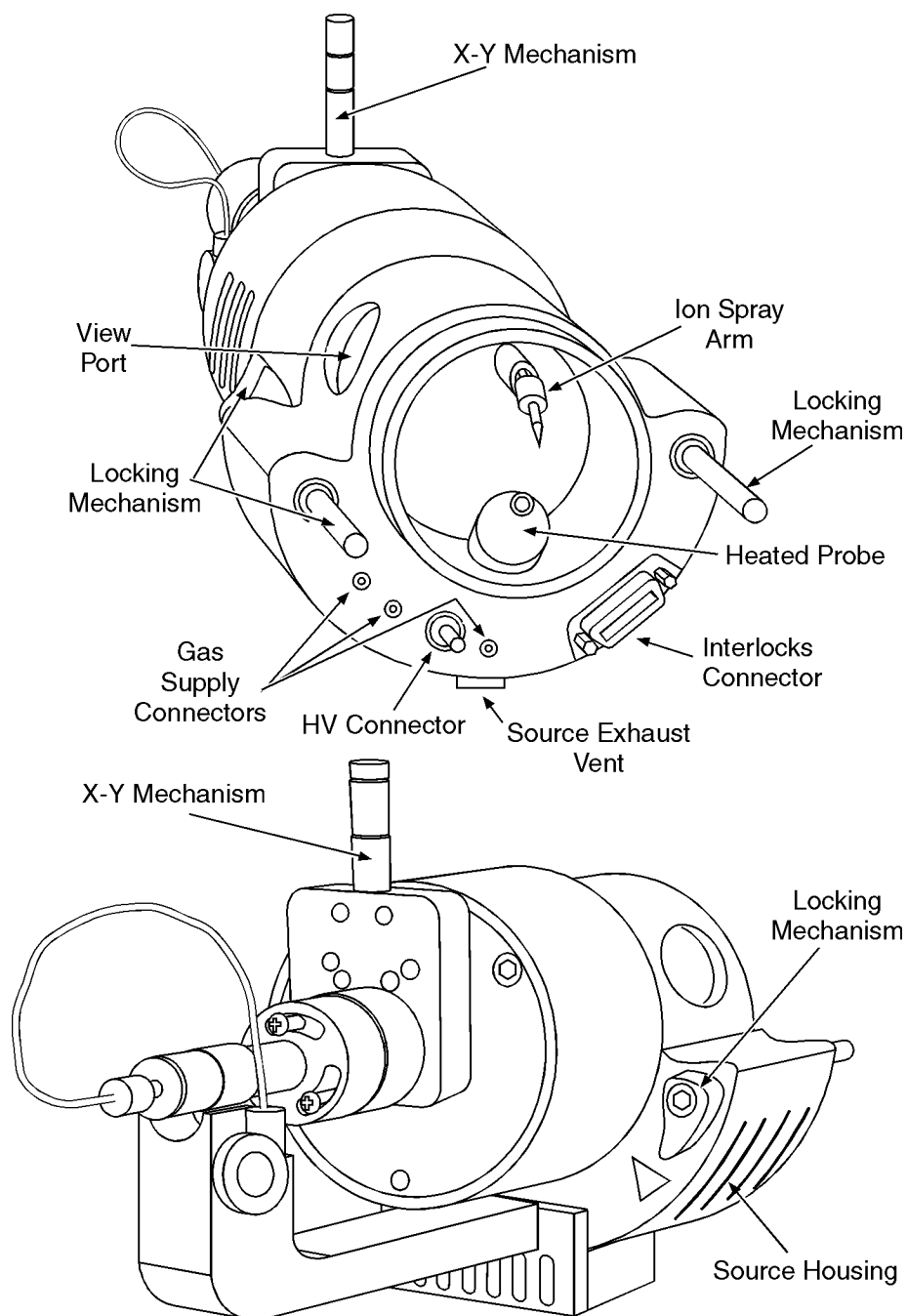


**Figure 2-3. TurbolonSpray Inlet and Ion Source**

Gas, High Voltage, and the Source Identification key are made through the front plate of the interface. LC inlet and splitter connections are on the front and front side of the Ion Source. A sample waste tube connected to the bottom of the Ion Source allows the venting of sample waste via the Source Exhaust System.

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## 2.2.4 Ion Source Interlocks

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**WARNING**     *Do not rely solely on the Interlocks to ensure your safety from the instrument's high voltage. When performing routine maintenance, ensure that the main circuit breaker is off and the main power supply is disconnected.*

---

The Source Interlock Assembly is connected to the Source Cover beneath on the Ion Source Housing (see the TurbolonSpray Unit Plug Connection figure). Direct wiring attached to the bottom of the Ion Source Housing is used to trigger the interlock microswitches on a PC board inside the Source Interlock Assembly. When a valid Ion Source is properly installed, an electrical field is generated that closes the interlock switches. If a valid Ion Source is not installed or installed incorrectly, the switches open, activating the interlocks. This interrupts a signal from the System Controller, disabling the high voltages and setting the ion optic voltages to zero. For more information on the system's power supplies, refer to the *Power and Electronics* section in this manual.

Restricting tool access to the Front and Back covers ensures that they cannot be taken off while the system's high voltages are applied.

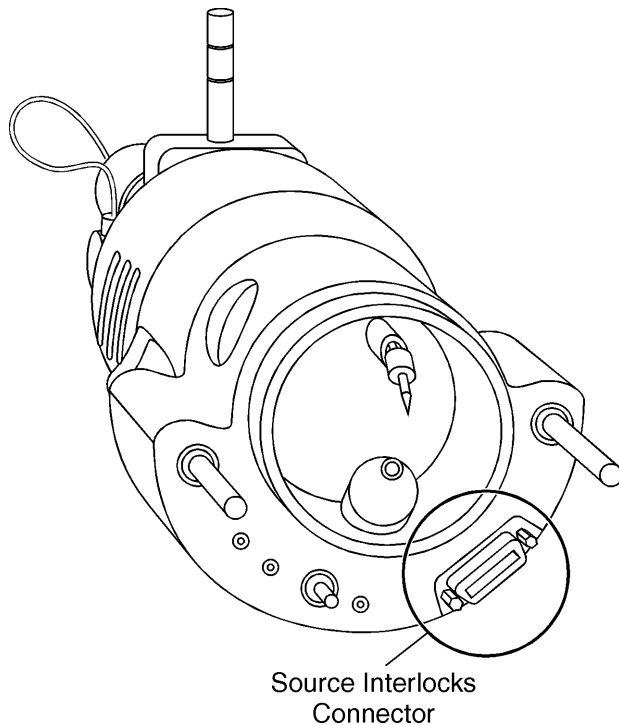


Figure 2-4. TurbolonSpray Unit Plug Connection

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The circuit board inside the Source Interlock Assembly also contains circuits that recognize the type of Ion Source installed. The Ion Source housings for the Heated Nebulizer and TurbolonSpray inlets trigger different sets of switches in the Interlock Assembly that sends information to the System Controller indicating the type of Ion Source installed. The System Controller uses this information to control the Source Exhaust System, a safety feature that isolates the Ion Source Exhaust products from the laboratory equipment.

---

## 2.3 Source Exhaust System

Each of the Ion Sources produces both ions and solvents vapours. As the Ion Source is opened to the atmosphere, these vapours represent a potential hazard to the laboratory equipment. The Source Exhaust System is designed to safely remove and service the Ion Source exhaust products.

The Source Exhaust System is a venturi system that uses a flow of gas through a venturi tube to draw the Ion Source exhaust from the Ion Source. The exhaust, along with the air used to drive the venturi, is delivered to the gas connections panel at the rear of the instrument, where an external connection is available to remove the exhaust from the laboratory. The exhaust gas can be connected to a fume hood or to some other means to remove the gas safely from the laboratory.



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**WARNING**     *Take all necessary precautions to ensure the safe disposal of the Source Exhaust Gases.*

---

The TurbolonSpray and the Heated Nebulizer sources produce greater volumes of exhaust products because both use additional volumes of gas and heat to produce ions. As a result, using the Source Exhaust System is an essential component of these Ion Sources. In fact, when either the TurbolonSpray or the Heated Nebulizer source is installed, the firmware will not enable the instrument's electronics unless the Source Exhaust system is operating.



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**WARNING**     *If you are analyzing gases containing toxic or highly volatile chemicals or solvents, it is highly recommended that you use the Source Exhaust System.*

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**Note**     *The Source Exhaust System slightly reduces the pressure in the Ion Source. The reduction in pressure has proven to be beneficial for the ionization performance of both the Heated Nebulizer and TurbolonSpray Ion Sources.*

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## 2.4 Source Exhaust Venturi Gas Supply

The venturi system is driven by an external supply of gas regulated to a maximum pressure of 60 psig. The gas has no chemical requirements because it is isolated from the Vacuum Chamber and is used solely to drive the Source Exhaust Venturi. The gas, normally compressed air, can be supplied by a “house supply”, a cylinder, or from a compressor (available as an option) from a 3rd-party vendor.

The external venturi gas supply is connected to the Exhaust Supply Connector on the gas interface panel and is fed directly to a solenoid valve that controls the gas flow to the venturi tube. The venturi output is connected to the “Exhaust Waste Out” connection on the Gas Interface panel. A third connection from the tube connects to the Source Exhaust Tube in the Interlock Assembly below the Ion Source (see the API 2000 - Source Exhaust Pump figure).

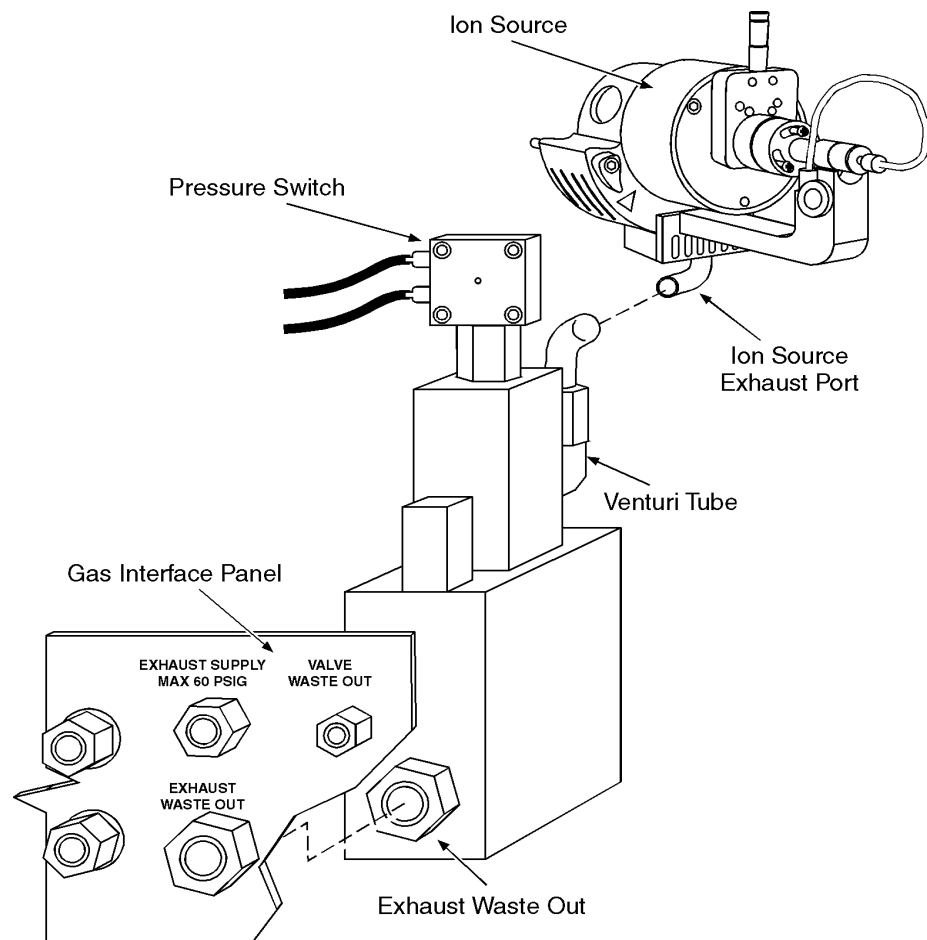


Figure 2-5. API 2000 - Source Exhaust Pump

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This figure shows the gas flows through the venturi system. The solenoid valve is operated by a 230 VAC connection directly from the AC Distribution. A switch on the AC Distribution controlled by the System Controller switches power to the solenoid valve whenever a valid Ion Source is installed. When the power is switched to the solenoid valve, it opens, enabling the gas flow through the venturi tube.

A pressure switch attached to the Source Exhaust Line is monitored by the System Controller. The switch status indicates the operational status of the Source Exhaust System. Should the pressure in the line rise above the trip point (0.1 in. water), the System Controller assumes that the Source Exhaust System is 'OFF'. If this occurs when either the TurbolonSpray or the Heated Nebulizer gas is installed, the System Controller interrupts the Power Supply Enable signal causing the instrument's electronics to shut down.

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|             |                                                                                                                                                                                                                                      |
|-------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>Note</i> | <i>When the pressure in the exhaust line falls below the set point of the instrument's electronics, the System Controller automatically restores the Power Supply Enable signal, and the instrument's electronics are activated.</i> |
|-------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

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With the TurbolonSpray source attached, a rise in pressure that trips the pressure switch does not disrupt the Power Supply Enable signal. Instead, a warning appears on the Application's Computer stating that the pump is not operating.




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|                |                                                                                                                                                                                                                                                 |
|----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>WARNING</b> | <b><i>With the TurbolonSpray Source attached, the instrument will operate if the pressure in the Source Exhaust Line exceeds the trip point. However it is strongly recommended that the Source Exhaust System be left on at all times.</i></b> |
|----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

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Whenever an instrument is switched on and an Ion Source is installed, power to the Source Exhaust solenoid is switched 'ON' initiating the venturi gas flow. The solenoid valve has no manual or software control. The adjustable flow control valve at the Source Panel provides a means to control the draw on the Ion Source. Opening the valve increases the gas flow to the venturi and the draw on the Ion Source, but lowers the pressure in the exhaust line. Conversely, closing the valve decreases the gas flow in the venturi and increases the pressure in the Source Exhaust Line.

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|             |                                                                                                                                                                                                                                                                                                                                                                                |
|-------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>Note</i> | <i>The TUNE software must be running before the Source Exhaust Pump will turn on. The pump will remain on after the TUNE software stops running. An <b>overnight quit</b> function shuts off the Source Exhaust Pump. Windows NT and MAC users should choose <b>Standby</b> from the <b>Acquire</b> menu. This command is equivalent to the <b>overnight quit</b> command.</i> |
|-------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

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|             |                                                                                                                                                                                                                                                                                     |
|-------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>Note</i> | <i>Closing the valve causes pressure to rise and can trip the pressure switch. Depending on the Ion Source attached, this can disable the system's electronics and interrupt any ongoing data acquisitions. Ensure that you open the valve when the pump is operating normally.</i> |
|-------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

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## 2.5 TurbolonSpray Inlet

The TurbolonSpray Inlet (see the next figure) consists of one unit: the TurbolonSpray Source. The Analyst software controls the flow of the Turbo Heater Gas (Gas 2).

The TurbolonSpray has a fixed angle adjustable TurbolonSpray probe and a fixed position TurboProbe. All electrical and gas connections are made through the interface. The Turbo Heater temperature is set at the Applications Computer using the TUNE software by modifying the TEM parameter in the State Window. The correlation between the parameter value of TEM and the actual heater temperature is direct (for example TEM 350 is equal to 350°C at the heater). The TurbolonSpray gas is connected to Gas 2 through the interface and is UHP nitrogen (99.999%) or zero air (99.999% purity) at flow rates of up to 8 L/min.

The TurboProbe temperature, which is set at the Applications Computer, is maintained by the Temperature Control Board (TCB) mounted behind the Front panel (below the IonSource housing). The TCB adjusts the flow of power to the heater element as a function of the difference between the actual heater temperature and the temperature setting at the Applications Computer. The probe temperature is monitored by a thermocouple connected directly to the heater element that maintains the temperature within  $\pm 15$  degrees of the Applications Computer setting. The operating range for the probe is from 100°C to approximately 500°C.

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|      |                                                                                                                                                                                                                                                                            |
|------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Note | <i>The temperature is controlled by monitoring the output of the thermocouple connected to the heater surrounding the metal tube. The thermocouple output is compared with the temperature setting at the TCB. The difference determines the power flow to the heater.</i> |
|------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

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The operating temperature should be adjusted relative to the LC mobile phase composition and flow rate. In general, a combination of heat and gas flow that allows the liquid spray to reach dryness before reaching the Curtain Plate will provide optimum performance.

The TurbolonSpray probe is adjustable in two directions: towards the orifice from a scale of 0 to 15 (adjustable by the X-Y mechanism mounted on the TurbolonSpray probe, and side-to-side across the orifice from  $\pm 5$  to 0 by the Lateral Adjustment control on the X-Y mechanism.

Turbo gas flows of approximately 5 L/min can be considered optimum for conditions where heat is required. Ionization efficiency is improved with the input of heat for all liquid flow rates. However, at lower flow rates (<20  $\mu\text{L/min}$ ), the gains are small. Heat inputs may be desirable under low flow conditions for the additional reason of enhancing in-source

(orifice-skimmer) fragmentation. Temperatures as low as 80° - 100° C have proven useful for enhancing the capability (for example, phosphopeptide mapping) when operating at low flow rates.

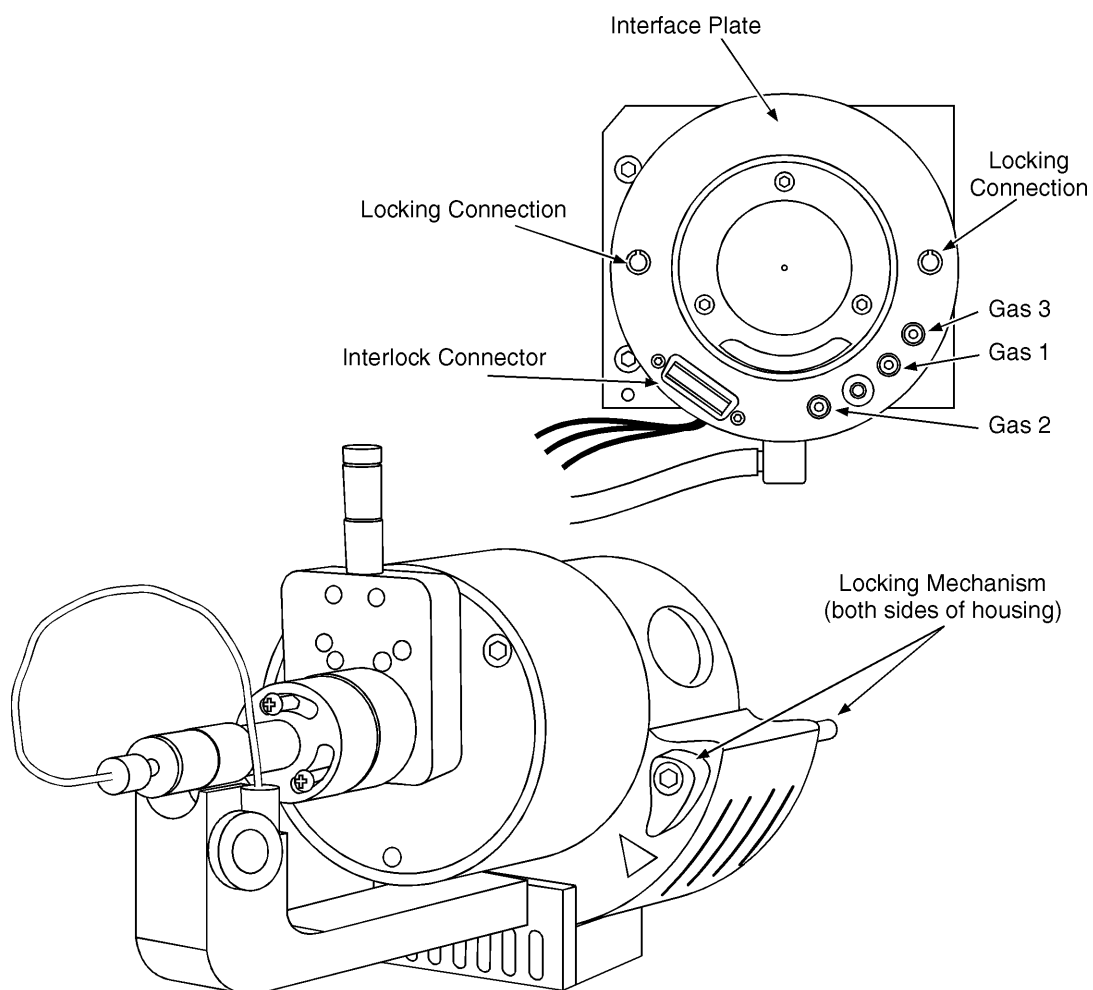


**Figure 2-6. TurbolonSpray Unit**

For more information, see the *TurbolonSpray Ion Source Manual*.

## 2.6 Service Procedures

### Assembling the Turbolon Spray

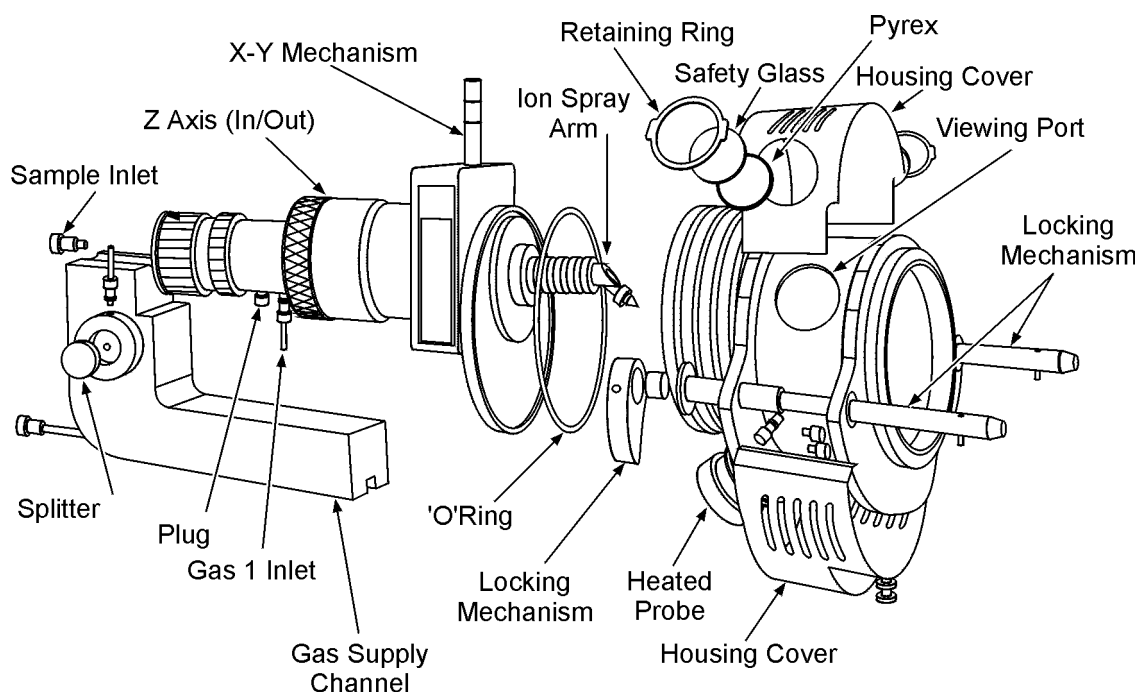


**Figure 2-7. Turbolon Spray Schematic**

1. Install the gasket, the two windows and spring into the source housing assembly. Using a spring tool, compress the spring, then rotate it 90° clockwise to the lock position.
2. Place the O-ring into the vent fitting and insert this assembly into the opening of the source housing.
3. Place the spring against the vent fitting and mount the Top Cover on the housing using the screws and lock washers.
4. Connect the two gas fittings to the housing, then using the screws, attach the connector strip. Loosely insert the set screw.
5. Slide the latch bushing onto the handle rod noting the orientation of the flange. Slide the spring onto the handle.
6. Using the spring pin, attach the handle to the handle rod. Ensure that the handle points in the same direction as the pin on the handle rod.
7. Carefully insert the handle assembly into the source housing. Support the handle to ensure that the handle spring compresses.

- 
8. Using external retaining ring pliers, install the retaining ring in the handle rod ensuring that it straddled the rod pin. Slide the clip past the pin. While compressing the spring, carefully insert the retaining ring into the groove of the handle rod. Be careful not to stretch the retaining ring.
  9. Using the two screws and the lock washers, attach the cable assembly to the housing, then using a lock washer and nut, attach the ground wire from the cable assembly to the mounting screw.
  10. Connect the remaining wires from the cable assembly to the connector strip.
  11. Install the heater assembly on the housing and rotate the heater so that the RTD is closest to the front face of the housing. Gently tighten the set screw.
  12. Slide the teflon sleeving over the two heater leads and connect the RTD and heater leads from the heater assembly to the connector strip.
  13. Measure the resistance of the RTD and heater across the connector strip using a DVM. The values should be as follows:  
  
Red to Black  $20\Omega$   
White to Blue  $110 \pm 10\Omega$   
White to Yellow  $110 \pm 10\Omega$   
Blue to Yellow  $5 \pm 2\Omega$
  14. Measure the resistance from each terminal on the connector strip to the ground. All terminals should read  $>10M\Omega$  to ground.
  15. Place the O-ring into the X-Y mechanism and secure the X-Y mechanism to the housing using the O-rings and screws.
  16. Using a screw and lock washer, attach the tee to the handle. The tee hole should face away from the housing.
  17. Cut the tubing to the required length. Using the appropriate fitting and ferrule, attach the tube to the probe assembly, then route the tubing through the housing and attach it to the barb fitting.
  18. From the outside, attach the HV cable to the housing by threading the fitting on the cable into the housing.
  19. Slide the clamp to the end of the probe, making sure that the threaded hole is correctly oriented.
  20. Gently screw the terminal end of the HV cable to the clamp to prevent the clamp from distorting.
  21. Route the gas tubing from the probe assembly through the slot in the handle and attach the handle to the housing using the screws and lock

washers.

22. Using retaining ring pliers, attach the retaining ring to the HV connector on the HV cable. Place the ring into the groove at the wire end of the connector. Insert the HV connector into the housing and attach it to the housing using the two retaining rings.
23. Using the screws and lock washers, reattach the bottom cover.
24. Install the union fitting into the tee. Attach the other end of the tubing to the probe assembly.
25. Attach the appropriate labels.

### Assembling the TurbolonSpray X-Y Mechanism

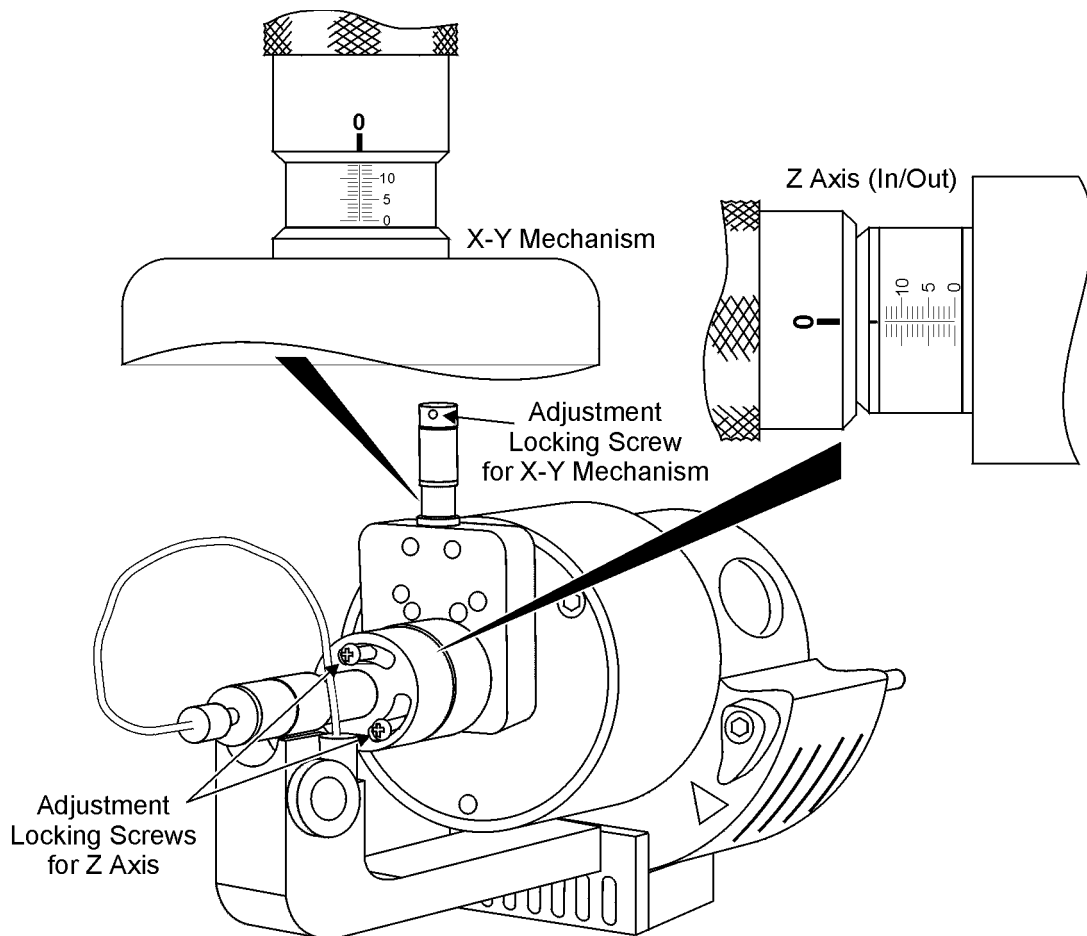


**Figure 2-8. TurbolonSpray X-Y Mechanism**

1. Remove the nut from the micrometer head and unscrew the head to the 12mm position. Place the nut in the guide slot in the top of the

- 
- guide and thread the micrometer head into the nut. Align the micrometer scale with the set screw hole in the top guide (keeping the nut snug), install the set screw and tighten the micrometer jam nut.
2. Loosely install the four remaining set screws into the top guide.
  3. Install two bearings into each side of the bottom guide. Ensure that the bearings are fully seated in the guide.
  4. Place the bottom guide into the top guide making sure that the bottom guide ball is facing the micrometer head. Install the shafts into the top guide until the ends of the shafts protrude through the bottom guide. Slide the springs on the shafts and tighten the four set screws.
  5. Attach the guide assembly to the housing plate using the four screws.
  6. Attach the appropriate label on the shaft holder.
  7. Install the O-ring and its bearing in the shaft holder.
  8. Trim the other bearing and insert it in the shaft holder making sure that you align the gap in the bearing with the shaft holder's hole.
  9. Attach the shaft holder assembly to the guide assembly (with the label facing the micrometer head) using the four screws.
  10. Install the O-rings in the bottom plate, twisting (to prevent damage to the O-ring) the plate assembly (with the O-ring facing the plate) on the end of the shaft holder and up to the bottom plate.
  11. Place the spring on the end of the shaft holder and screw on the bottom nut.
  12. Place the spring in the notch left of the slot (90° counterclockwise) over the long end of the T-shaft.
  13. Push the spring and the T-shaft into the shaft holder making sure that the other end of the spring goes into the hole in the shaft.
  14. Compress the spring, rotate the shaft slightly counterclockwise, and install and tighten the locking pin through the hole on the top guide.
  15. Attach the outside nut to the inside nut using the two screws making sure that the screws are in the center of the slots before tightening them.
  16. Install the washer on the T-shaft and place the nut assembly over the end of the shaft. Compress the shaft spring and thread the nut assembly on the T-shaft until "0" is reached on the scale.
  17. Place two O-rings in the probe insulator, then lubricate the O-rings with water and insert the insulator into the T-shaft.

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|             |                                                                                                                                                         |
|-------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>Note</i> | <i>When the first O-ring passes the hole in the shaft, carefully compress the O-ring to prevent it from tearing as the insulator is fully inserted.</i> |
|-------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|

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18. Rotate the probe so that the probe's holes line up with the holes on the T-shaft.
19. Place the O-ring on the probe's tip and thread the tip into the probe tube.

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|             |                                                                                                                                   |
|-------------|-----------------------------------------------------------------------------------------------------------------------------------|
| <i>Note</i> | <i>Carefully screw the tip into the probe to prevent the O-ring from pinching. The O-ring must be completely inside the tube.</i> |
|-------------|-----------------------------------------------------------------------------------------------------------------------------------|

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20. Place the O-rings on the probe tube, then carefully insert the probe tube into the probe insulator making sure not to catch the O-rings. To minimize catching the O-rings, rotate the probe as it is inserted.
21. Install the O-ring on the tube nut. Using tweezers, drop the nut on the end of the tube assembly and tighten the nut until it bottoms. Blow out the end of the probe with compressed air to remove any particles.
22. Install the O-rings in the fitting nut, and then place the ferrule into the fitting. Insert the electrode into the fitting, slide the nut assembly over the electrode and tighten it into the fitting.
23. Place the spring into the end of the T-shaft and carefully insert the electrode assembly into the probe tube.
24. Thread the jam nut into the end of the T-shaft.
25. Insert the O-ring into the probe nut and thread the nut assembly into the end of the T-shaft to hold the electrode assembly in place, making sure that the electrode nut fits properly into the slots of the T-shaft.
26. Insert the O-ring into the probe insulator and install the plug fitting into the T-shaft making sure that the hole in the T-shaft lines up with the hole in the probe insulator prior to assembly.

### **Removing the Ion Source**

1. Finish or abort any ongoing scans.
2. Shut down the sample flow to the Ion Source.
3. Loosen the two latches attaching the Ion Source to the Vacuum Interface Housing. Turn the latches outwards until the Ion Source Housing is loose.
4. Pull the Ion Source away from the Vacuum Chamber so that the latches clear the connections in the Vacuum Interface Housing.

### Opening the TurbolonSpray Ion Source

1. Finish or abort any ongoing scans.
2. Shut down the sample flow to the Ion Source.
3. Turn the latches on the front plate of the source. See the TurbolonSpray Inlet and Ion Source figure.

---

*Note*                      *Loosen the latches completely, but be aware that they cannot be removed.*

---

4. Remove the TurbolonSpray source from the front of the API 2000 instrument.

### Removing the Peek Tubing

1. Unscrew the Peek tubing fittings from the probe inlet and grounded union/splitter fitting and discard the old tubing (the fittings may be re-used if they have not been over-tightened and damaged). (see the TurbolonSpray Assembly figure).

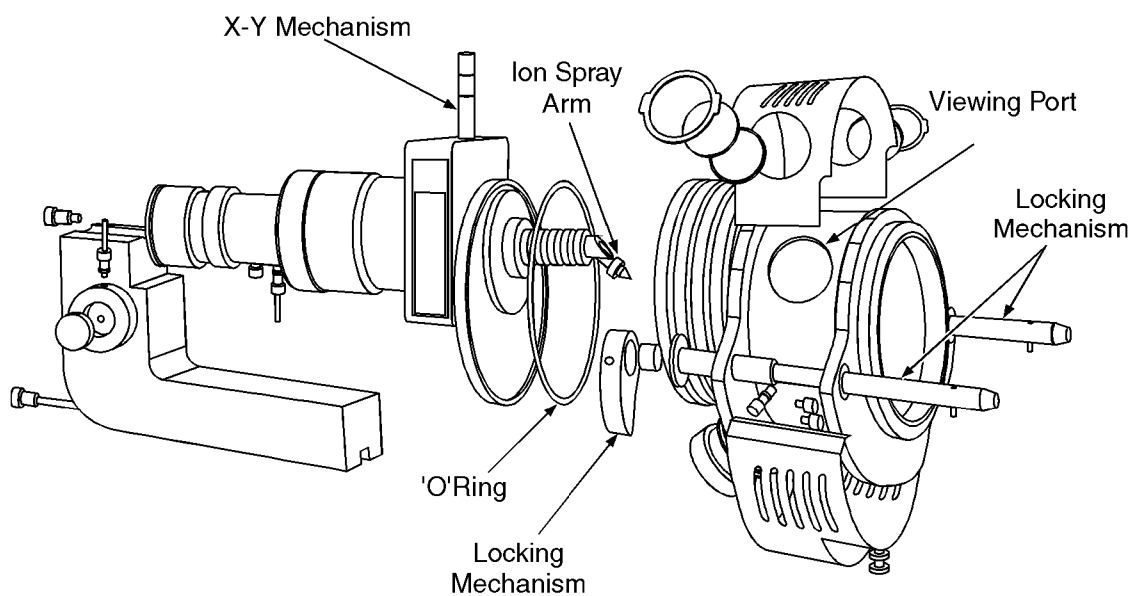


Figure 2-9. TurbolonSpray Assembly




---

**WARNING**      *Peek tubing (or Fused Silica) with Peek fittings must be used as the transfer line. Metal tubings or fittings must not be used. The use of metal may expose the user to High Voltage.*

---

- 
2. Obtain a new piece of 0.0025" Peek tubing (it must be at least 30 cm long) and place Peek connection fittings on each end.
  3. Connect the Peek tubing to the probe inlet and grounded union/splitter fitting.

### Changing The Stainless Steel Sprayer Tube

The standard TurbolonSpray set-up uses a 0.004" (100  $\mu$ m) ID metal sprayer tube. The procedure outlined below should be used to exchange the metal tube in the TurbolonSpray in the event of blockage or degradation of the sprayer tip.

1. Remove the TurbolonSpray and set on its side.
2. Disconnect the Peek transfer line from the probe inlet.
3. Unscrew and remove the black inlet probe fitting. A Peek union, metal spring and the metal sprayer tube can now be removed from the probe.
4. Unscrew the fitting holding the metal tube to the Peek union. Remove the tube from the fitting and discard. Do not discard the fittings.

---

|             |                                                                                                                                                          |
|-------------|----------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>Note</i> | <i>If you prefer, the procedure can be performed by removing the Ion Source to a work table to perform the maintenance procedures on the Ion Source.</i> |
|-------------|----------------------------------------------------------------------------------------------------------------------------------------------------------|

---

5. Place a new sprayer tube and ferrule in the fitting and screw into the Peek union. Ensure that the sprayer tube is placed as far as it can go into the Peek union to guarantee a leak-proof seal (two wrenches should also be used to tighten the fittings).
6. Place the metal spring and metal tube/Peek union back into the probe.
7. Place the black inlet probe fitting over the Peek union and tighten. This fitting is used to adjust the protrusion of the metal sprayer tube tip at the end of the probe. The metal tube should protrude approximately 0.75 mm, although a protrusion between 0.5 to 1.25 mm is also acceptable.

### Changing The Grounded Union/Splitter Fitting

A Peek tubing transfer line connects the sprayer probe inlet to a grounded fitting that can be used either as a union or splitter. Since the liquid being sprayed from the source is in contact with high voltages, the transfer line must be connected to the grounded fitting.

---

**WARNING**     *The use of the Peek tubing transfer line connected to the grounded fitting is mandatory since it prevents any exposed peripherals connected to the source from floating at high voltage.*

---

The procedure outlined below should be used to change between the union and splitter insert fittings.

1. Remove the TurbolonSpray and set on its side.
2. Disconnect the Peek transfer line from the ground fitting.
3. Disconnect any other fittings or tubing that may be connected to the grounded fitting.
4. The insert within the grounded fitting should now move freely and can be removed by tilting the source and allowing it to fall out.
5. Place the new insert into the fitting and align it such that all the openings match.
6. Connect the Peek transfer line to the grounded fitting and any other fittings or tubing that may be used.

---

**WARNING**     *Peek tubing (or fused silica) with Peek fittings must be used as the transfer line. Metal tubing or fittings must not be used. The use of metal may result in the exposure of high voltage to the user.*

---

---

## Removing the Electrode Tube

The electrode tube sticks out past the nebulizer tip. When installed, the sprayer electrode becomes the end of the sprayer and carries the Ion Source high voltage. The silica tubing slides through the electrode tubing.

1. Remove the TurbolonSpray source.

---

|             |                                                                                                                                                         |
|-------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>Note</i> | <i>If you prefer the procedure can be performed by removing the Ion Source to a work table to perform the maintenance procedures on the Ion Source.</i> |
|-------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|

---

2. Using a 4" adjustable wrench, loosen the nozzle nut at the end by turning it counterclockwise.
3. Remove the nozzle nut.
4. Using a pair of tweezers, carefully remove the electrode tube.

### Replacing the Electrode Tube

1. Slide the electrode tube between the lips of the Nebulizer tube.
2. Thread the Nebulizer tube into the teflon sleeve.
3. Using an adjustable 4" adjustable wrench, give the teflon sleeve a 1/4 turn.

### Cleaning the Sprayer Electrode Tube

This electropolishing procedure is used to clean the TurbolonSpray electrode tube. It should be cleaned, as required.

The cleaning process requires the following equipment:

- One DC power supply (0 to 24V and 0 to 1A variable)
  - One microscope
  - Three copper or stainless steel crocodile clips
  - Two stainless steel rods or tubing for use as cathodes
  - One polypropylene (nalgene) container for electrolyte
  - A solution of 60% phosphoric acid ( $\text{H}_3\text{PO}_4$ ), 20% sulfuric acid ( $\text{H}_2\text{SO}_4$ ) and 20% water for use as electrolyte
1. Use crocodile clips to connect the two cathodes to the negative pole of the power supply and the sprayer nozzle to the positive pole of the power supply, as shown below.

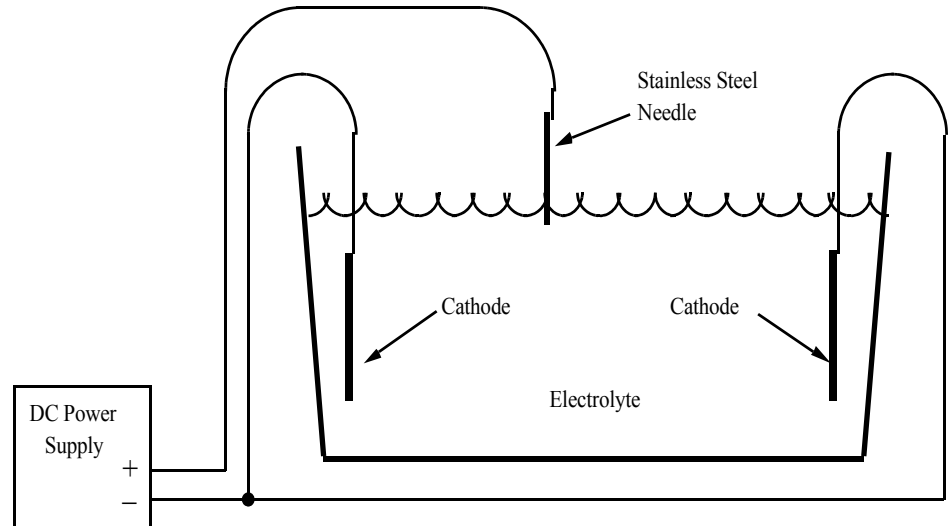


**Figure 2-10. Electropolishing Apparatus**

2. Immerse 5 mm (3/16") of the electrode tube tip into the electrolyte bath.
3. Adjust the current on the power supply to 100 mA.
4. Slowly move the nozzle back and forth in the electrolyte for approximately two seconds. Moving the electrode tube minimizes bubble buildup around the area to be electropolished.
5. Rinse the electrode tube in water and examine the electropolished area under a microscope to verify that the area is smooth and undamaged.
6. If necessary, repeat steps 2 to 5.

---

## 2.7 Source Exhaust System Service

### 2.7.1 Venturi Gas Supply

Maintenance procedures on the gas supply source exhaust system are few as the potential failure points are small and easy to isolate. However, the source exhaust system is an important safety feature and if it is not functioning, it may prevent the instrument from operating.

There are three main console components that could cause the Source Exhaust System to fail. They are:

- Solenoid valve
- Pressure switch
- AC Distribution

If these systems are functioning and the system fails to operate, a plumbing problem, such as a substantial leak in the venturi line or a blocked gas line, may be the cause of the problem.

The assembly schematic shows the system plumbing connections.

If the source exhaust system is failing, complete the following diagnostic procedures with the instrument on, pumped down, the Source Cover closed, and an Ion Source installed:

1. Ensure that the venturi gas supply is properly connected and supplying the instrument.
2. Open the flow control valve on the Source Panel.
3. Check the pressure switch. Jump the switch connectors with a paper clip. If that causes the system to work, replace the switch (see the API 2000 - Source Exhaust Pump figure).
4. Confirm that AC power is reaching the solenoid valve. Check that Pin 3 on the connector to the solenoid valve is live. If not, replace the AC Distribution Board. For procedures on replacing the AC Distribution, refer to the *Power and Electronics* section in this manual.

## 3 Vacuum Interface

### 3.1 Overview

The Vacuum Interface separates the low pressure Vacuum Chamber from the atmospheric pressure in the Ion Source. The purpose of the Vacuum Interface is to allow the transfer of ions from the Ion Source to the Mass Spectrometer while restricting sample, solvent and ambient air from entering the Vacuum Chamber. This is accomplished using a “gas curtain” of dry nitrogen.

The Vacuum Interface (see the figure below) comprises two distinct pressure chambers: the Gas Curtain Interface and the Differentially Pumped Interface. The two interface regions are separated by the Orifice Plate that contains a 0.10” orifice through which the ions and a small volume of Curtain Gas must pass before entering the Vacuum Chamber.

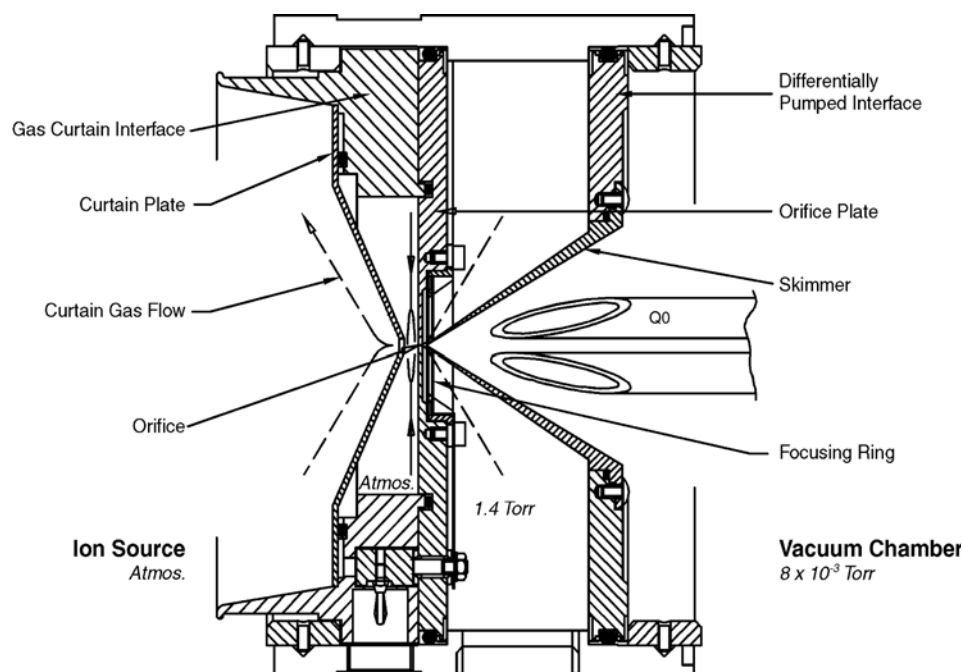


Figure 3-1. Vacuum Interface - Side View

---

Ions are transferred from the Ion Source through the Vacuum Interface into the Vacuum Chamber by the potential gradient across the Vacuum Interface. The operator can adjust the ion flow by varying the voltages applied to the Orifice Plate and the Focusing Ring. The Curtain plate voltage is fixed and varies only in polarity depending on the polarity of ions to be analyzed.

The Vacuum Interface is bolted to the main body of the Vacuum Chamber for easy access to the interface and to the front bulkhead of the Mass Filter Rail. For more information on the Mass Filter Rail, refer to the *Vacuum Chamber* section in this manual.

### 3.1.1 Gas Curtain Interface

The Gas Curtain Interface is a small volume chamber at atmospheric pressure that is flushed with a pure, inert Curtain Gas (nitrogen is recommended). Curtain Gas is pumped into the interface at a rate ranging from 0.6 to 2.0 L/min. Approximately 600mL/min of Curtain Gas flows through the Orifice into the Differentially Pumped Interface, while the remaining flows back into the Ion Source through the aperture in the Curtain Plate.

The Gas Curtain Interface provides a region for ion declustering. In the interface, sample ions collide with the gas molecules. The collisional energy assists in breaking ion clusters and separating the sample ions from solvent molecules. The controlled inert atmosphere in the interface helps to retain the stable ion-molecule products from the Ion Source.

The Curtain Gas' flow rate is set from the Applications Computer and is physically controlled by a variable orifice valve controller. A detailed description of the Organ Pipe and the Curtain Gas Control is contained in the *Vacuum Control System* section in this manual. The gas line is connected to the Gas Curtain Interface through a connection on the bottom of the Vacuum Interface, as shown in the next figure.

To protect the sensitive components of the instrument, the Curtain Gas flow is interlocked to the Pumping System and Ion Optics. If the Curtain Gas pressure is more than 5 psig from the required pressure, the System Controller disables the high-voltage supplies, sets the ion optic voltage to zero, and turns off the Turbomolecular Pumps. When the gas flow is restored, the System Controller automatically restarts the Turbomolecular Pumps and attempts to recover the operating conditions. For more information on the Curtain Gas control and safety locks, refer to the *Vacuum Control System* section in this manual.

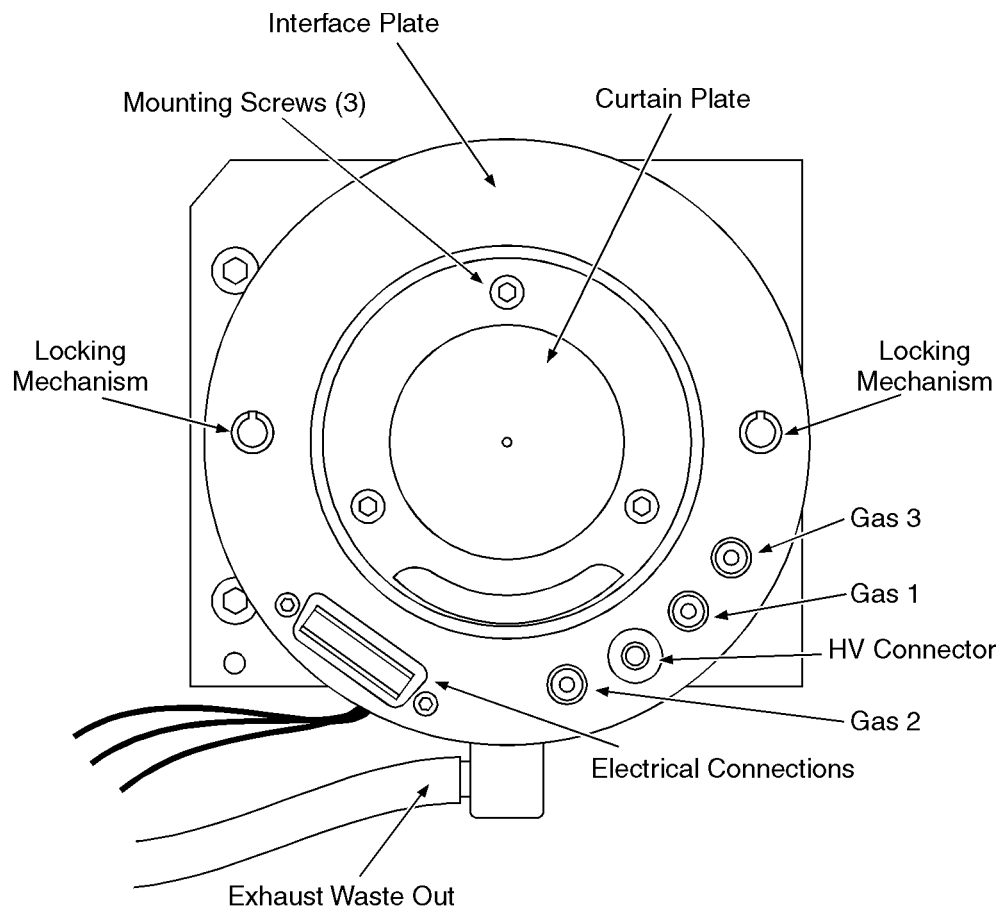


**Figure 3-2. Vacuum Interface - Front View**

### 3.1.2 Differentially Pumped Interface

The Differentially Pumped Interface is the first low-pressure stage in the transition from the atmospheric pressure Ion Source to the low pressure Vacuum Chamber. The pressure in the interface is maintained below 1.4 torr by the D16 Rotary Vane Interface Pump that is located outside the Main Console. This pumping system is explained further in the *Vacuum Control System* section in this manual.

Curtain Gas and ions are drawn from the Curtain Gas Interface into the Differentially Pumped Interface by the pressure differential across the Orifice Plate. The ions are further drawn through the Differentially Pumped Interface by the voltage difference (for example, declustering voltage) between the Orifice Plate and the Focusing Ring. The ions enter the Vacuum Chamber through the aperture in the Skimmer.

Vacuum lines connect the Interface Pump to the port underneath the Differentially Pumped Interface (see the previous figure). The pump is interlocked to the ion optics and the Pumping System by a pressure switch connected to the vacuum port. If the pressure in the interface rises sharply, the switch trips, notifying the System Controller of an Interface Pump fault.

The System Controller, upon receiving the indication of a pump fault, disables the high-voltage power supplies, sets the ion optic voltages to zero, and turns off the Turbomolecular Pumps until the pressure in the Differentially Pumped Interface is restored.

Pure nitrogen is fed as CAD Gas to the Collision Cell in the Vacuum Chamber. For more information, refer to the *Collision Cell* section in this manual.

### 3.1.3 Entrance Optics

The Entrance Optics consist of the Curtain Plate, the Orifice Plate, and the Focusing Ring. Voltage potentials applied to these elements help guide the sample ions through the Vacuum Interface. The voltages applied to the Orifice Plate and the Focusing Ring are controlled by the operator from the Applications Computer. The Curtain Plate voltage is fixed. Depending on the ions' polarity (as determined by the operator), the Curtain Plate's polarity is automatically set. It is also heated up to 80°C to help with desolvation.

**Table 3-1. Entrance Optics Functions**

| Optic Element                                                                                                                                                        | Function                                                                                                                                                                                                                                                                                                               |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Curtain Plate                                                                                                                                                        | <ul style="list-style-type: none"> <li>- separates the sample flow from the curtain gas flow</li> <li>- is electrically isolated from the vacuum housing so that the ions are not constrained to pass through ground potential at this point</li> <li>- ensures that the voltage is the computer-controlled</li> </ul> |
| Orifice Plate                                                                                                                                                        | <ul style="list-style-type: none"> <li>- provides a division between atmosphere and the approximately 1.4 torr pressure of the Differentially Pumped Interface</li> <li>- contains the 0.010" orifice</li> <li>- is electrically isolated*</li> </ul>                                                                  |
| Focusing Ring                                                                                                                                                        | <ul style="list-style-type: none"> <li>- focuses the ions through the Skimmer into the Vacuum Chamber</li> <li>- is electrically isolated*</li> </ul>                                                                                                                                                                  |
| *The Orifice Plate and the Focusing Ring are electrically isolated such that a variable declustering voltage of 0 to $\pm 350\text{V}$ can be obtained between them. |                                                                                                                                                                                                                                                                                                                        |

The power supplies used to generate the voltages applied to these elements are located on the Lens Power Supply Board inside the System Electronics Box (refer to the *System Electronics Box Circuit Descriptions*

section in this manual). For a list of standard voltage settings, see the table below.

**Table 3-2. Entrance Optics Standard Voltage Settings**

| Component                                                                                                          | ID  | *MS   | *MS/MS | *Range |
|--------------------------------------------------------------------------------------------------------------------|-----|-------|--------|--------|
| Curtain Plate                                                                                                      | **  | +1 kV | +1 kV  | +1 kV  |
| Orifice Plate                                                                                                      | OR  | +35V  | +35V   | ± 200V |
| Focusing Ring                                                                                                      | RNG | +300V | +300V  | ± 400V |
| *Values are for positive ion mode. For negative ion mode, the voltages are the same, but the polarity is reversed. |     |       |        |        |
| **The curtain plate voltage is not controlled by the software.                                                     |     |       |        |        |

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## 3.2 Hook-up Schematic

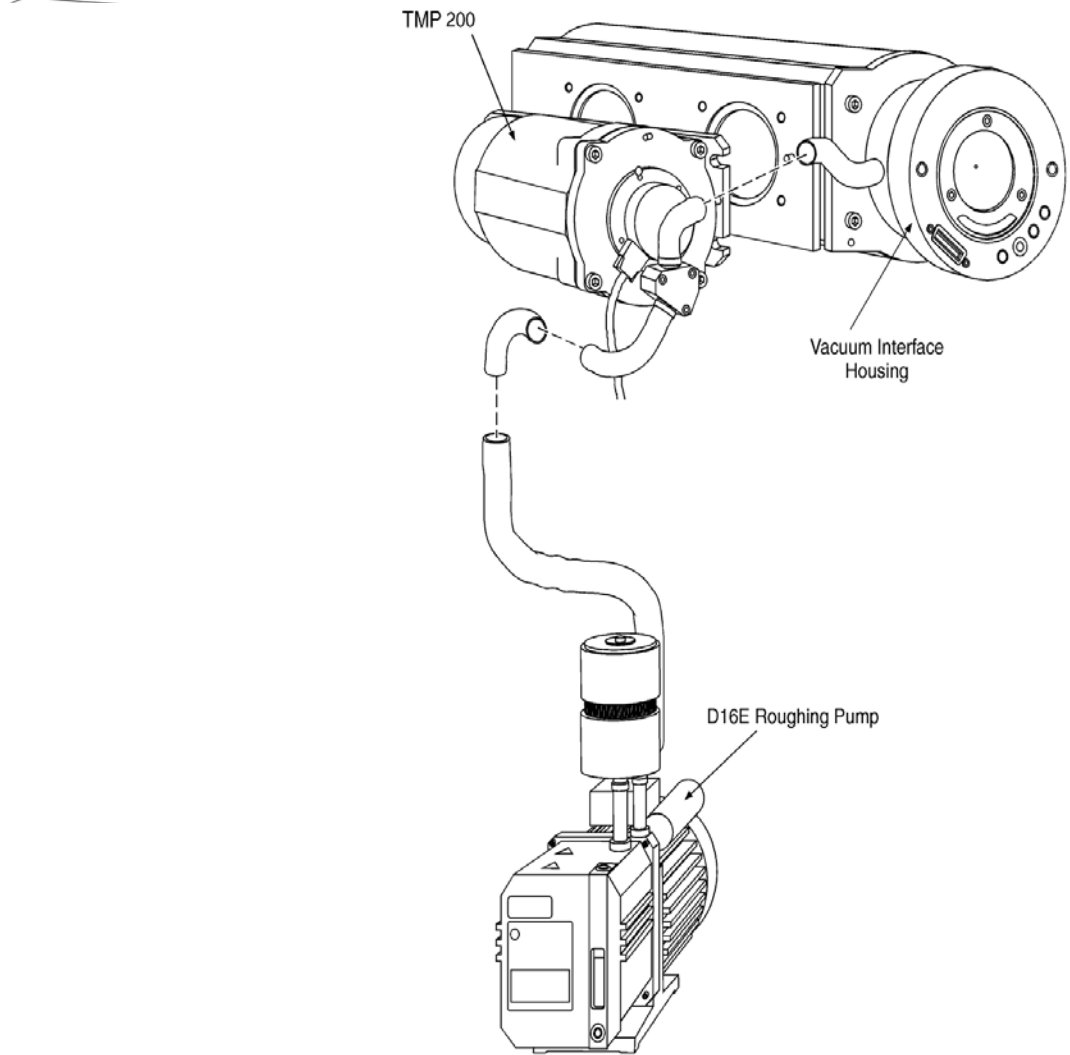


**Figure 3-3. Vacuum Interface Hook-up Schematic**

The Vacuum Interface is bolted to the Vacuum Chamber, and can be opened to expose both ends of the Interface and the front region of the Vacuum Chamber. All external connections, including the Curtain Gas, voltage connections, and vacuum line to the Interface Pump, are made through the Vacuum Interface Housing (see the figure above).

---

## 3.3 Vacuum Interface Maintenance

### Assembling the Vacuum Interface

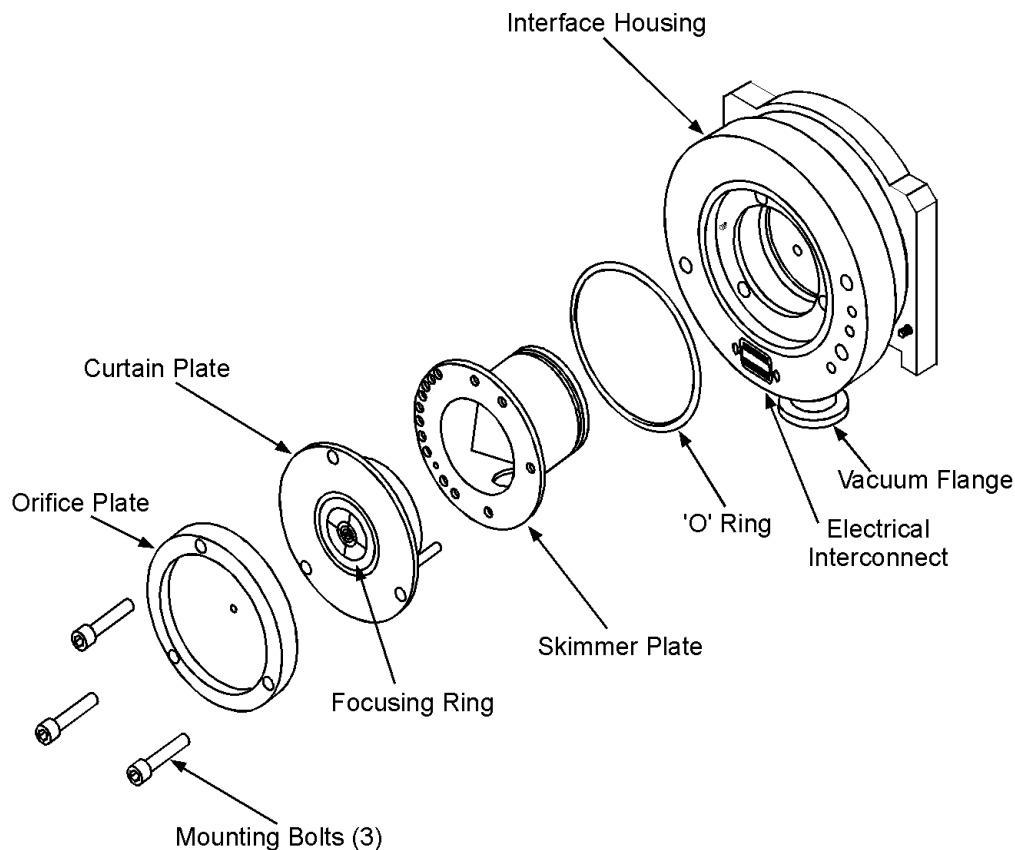


**Figure 3-4. Vacuum Interface Schematic**

To assemble the Skimmer and Orifice:

1. Using the lock washers and the nut, install the contact on the skimmer.
2. Install the O-rings on the skimmer.
3. Using your hand, press the skimmer and the orifice plate assembly together. Observe the orientation of the connector pins.
4. Using a soldering iron and an electronic grade solder, solder the pins together, making sure the pins are straight and tight against each other after soldering. Thread the completed assembly into the curtain plate.
5. Assemble the curtain plate on the skimmer/orifice assembly. Observe the orientation of the curtain plate. The connector assembly should line up with the through hole on the skimmer/orifice assembly. Press

---

the assembly together by hand.

To assemble the Vacuum Housing:

1. Place the O-ring into the vacuum fitting. Using the two screws, flat washers, and the lock washers, attach the vacuum flange to the housing.
2. Attach the gas supply fitting to the housing.

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|             |                                                                     |
|-------------|---------------------------------------------------------------------|
| <i>Note</i> | <i>This fitting comes with a nylon gasket. Do not over tighten.</i> |
|-------------|---------------------------------------------------------------------|

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3. Attach the warning label.
4. Place the two strips of Kapton tape over the solder side of the heater harness.
5. Using screws, lock washers, eyelets, flat washers, and nuts, attach the interface heater harness to the housing. Do not over tighten because the eyelets can be crushed.
6. Using the screw, flat washers, lock washers, and nuts, install the probe heater cable assembly to the interface housing.
7. Install the ground wire under one of the mounting screws.
8. Remove the nut, O-ring, heat shrink, and circlip from the cable assembly Ion Source HV#2.
9. Slide the HV cable through the housing and attach it to the housing using the circlip.
10. Slide the heat-shrink tubing back into the HV cable. With the heat-shrink tubing pressed tightly against the housing, shrink the tubing against the wire and connector.
11. Re-install the nut and the O-ring on the cable assembly.
12. Cut three pieces of tubing, each 65 cm. long. Push the tubing into the glass fittings.
13. Install the O-rings into the gas fittings and place the springs into the back of the gas fitting. Install the gas fittings through the front of the housing and secure it in place with retaining rings.
14. Attach the O-ring to the end of the interface drain and thread the drain into the housing. Gently tighten the drain because over tightening will cause the teflon ring to become distorted in the housing.
15. Install the O-ring in the fitting, and slide the assembly over the end of the source drain fitting.
16. Install the skimmer/orifice assembly, making sure that the PCB is

---

properly seated. Install the three mounting screws and gently tighten them.

17. Label the gas line (Gas 1, Gas 2, and Gas 3). Place the labels on the appropriate tubes approximately 5 cm from the loose end of the tubes.

### Opening the Vacuum Interface

1. Safely shut down the instrument.
2. Remove the Ion Source.

---

|             |                                                                                                                                                                            |
|-------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>Note</i> | <i>It is necessary to remove the Ion Source to open the Interface. Removing it makes it easy to maintain the interface and reduce the risk of damaging the Ion Source.</i> |
|-------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

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|             |                                                                                                                     |
|-------------|---------------------------------------------------------------------------------------------------------------------|
| <i>Note</i> | <i>Ensure that the Interface's ion optic voltage leads do not catch on the Source Panel as the Interface opens.</i> |
|-------------|---------------------------------------------------------------------------------------------------------------------|

---

### Cleaning the Vacuum Interface

The Interface components (Skimmer, Curtain Plate, Orifice and Focusing Ring) should be cleaned periodically to ensure optimal instrument performance. Cleaning will keep the orifice clear, reduce electrical noise and prevent samples from adhering to the Interface components and altering the electrical performance of the Interface.

Both the Curtain Plate and the Skimmer can be removed and cleaned with methanol and a clean lint free wiper (Kim Wipe™). You can clean the Orifice and Focusing Ring without removing them. Because they do have fragile components, extra care must be taken when cleaning them.




---

|                |                                                                                                                                                                                                                                                  |
|----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>WARNING</b> | <b><i>If hazardous, biohazardous, or radioactive materials have been analyzed in the instrument, take all necessary precautions as outlined on the material MSDS when cleaning the Interface, Ion Source, and Vacuum Chamber components.</i></b> |
|----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

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---

|                |                                                                                             |
|----------------|---------------------------------------------------------------------------------------------|
| <b>Caution</b> | <b><i>Do not spray solvent or water through the orifice or into the Vacuum Chamber.</i></b> |
|----------------|---------------------------------------------------------------------------------------------|

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|                |                                                                                                                                                                       |
|----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Caution</b> | <b><i>Take extreme care when cleaning the Orifice. Do not use a cleaning wipe or a wire. The Orifice is very thin and can easily be damaged. Do not sonicate.</i></b> |
|----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|

---

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|             |                                                                                                                                        |
|-------------|----------------------------------------------------------------------------------------------------------------------------------------|
| <b>Note</b> | <i>Always wear powder free latex gloves when cleaning the Interface. Keep the components and Vacuum Chamber free of dust and lint.</i> |
|-------------|----------------------------------------------------------------------------------------------------------------------------------------|

---

To clean the Interface:

1. Shut down the instrument.
2. Remove the Curtain Plate.
3. Remove the Skimmer.

---

|                |                                                                            |
|----------------|----------------------------------------------------------------------------|
| <b>Caution</b> | <b><i>The tip of the skimmer is fragile. Handle it very carefully.</i></b> |
|----------------|----------------------------------------------------------------------------|

---

4. Clean both the Curtain Plate and Skimmer with methanol and a clean lint free wipe. Spray the plates with dry gas to evaporate the residual methanol or allow them sufficient time to dry before reinstalling them.
5. From the Skimmer (Vacuum Chamber) side of the interface, gently clean the Focusing Ring and Orifice with a swab damp with methanol. Take care not to damage the Orifice.
6. Allow the methanol on the Orifice and the Focusing Ring to dry.
7. Replace the cleaned Skimmer and Curtain Plate. Follow the appropriate procedures.

---

## 3.4 Vacuum Interface Service Procedures

The Vacuum Interface is available as a Field Replaceable Unit (FRU) and can be replaced in the field as a complete unit. However, for most Interface field service repairs, the Interface can be disassembled and assembled with replacement parts. The Curtain Plate and the Skimmer can be replaced without disassembling the Interface.

### Removing and Replacing the Vacuum Interface Assembly

Follow this procedure to remove and replace the complete Vacuum Interface Assembly with a replacement assembly. The procedure essentially involves disconnecting and removing the Interface, and then installing the replacement.

To remove the Vacuum Interface:

1. Shut down the instrument.
2. Shut off all gas supplies.
3. Remove the Ion Source.
4. Disconnect the Curtain Gas' connection. See the Vacuum Interface Hook-up Schematic figure.
5. Disconnect the high voltage, interlocks coupling and gas connections (using C-spring pliers), the source exhaust, and the vacuum hose.
6. Disconnect the vacuum line from the vacuum flange.
7. While supporting the Interface, using a 5 mm Allen key, unscrew and remove the four screws that connect the Interface housing to Vacuum Chamber.
8. Remove the Interface.

To replace the Vacuum Interface:

---

|                |                                                                                                                                                                                                                                                  |
|----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Caution</b> | <b><i>Keep the replacement Interface clean and free of dust and lint. Do not open the assembly until just prior to installation. Wear powder-free latex gloves to prevent getting fingerprints on the exposed Curtain Plate and Skimmer.</i></b> |
|----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

---

1. Before installing the new Interface assembly, use a multimeter to confirm that:
  - There is electrical continuity between the Curtain Plate and the connector. See the Vacuum Interface Assembly figure.
  - There is electrical continuity between the Orifice Plate and the connector.

- 
- There is electrical continuity between the Focusing Ring and the connector.
  - The Focusing Ring and the Orifice Plate are electrically isolated. There should be no electrical leakage between the Ring and the Orifice Plate.
  - The Skimmer is grounded.
2. Hold the replacement Interface in position aligning it with the mounting holes of the Vacuum Chamber. Insert the four screws that secure the Interface housing.
- 

**Caution**      *The Q0 rods protrude into the Skimmer. Be careful not to damage the Q0 rods or the Skimmer when fitting the Interface.*

---

3. Adjust the Interface position so that the Interface housing fits flush with the Vacuum Chamber housing and then completely tighten the mounting screws.
4. Connect the high voltage, interlocks coupling and gas connections (using a C-spring pliers), source exhaust, and vacuum hose.
5. Connect the Curtain Gas to the Interface.
6. Re-clamp the vacuum line from the Interface Pump to the vacuum flange. See the Vacuum Interface Assembly figure.

### **Cleaning the Orifice/Skimmer Module**

The Vacuum Interface components should be cleaned periodically to ensure optimal instrument performance. Cleaning keeps the orifice clear, reduces electrical noise, and prevents sample and solvents from accumulating on the Interface components that can alter the electrical performance of the Interface.




---

**WARNING**      *If hazardous, biohazardous, or radioactive materials have been analyzed in the instrument, take all necessary precautions as outlined on the MDS material when cleaning the Vacuum Interface, Ion Source, and the Vacuum Chamber components.*

---



---

**Caution**      *Do not spray solvent or water through the orifice into the Vacuum Chamber.*

---

The front of the orifice can be cleaned without venting the instrument.




---

**WARNING**     *Using the overnight quit command before performing this procedure allows you to remove the Ion Source. To fully ensure that the high voltages are not applied, a full shutdown (without venting) should be used. Windows NT and MAC users should choose Standby from the Acquire Menu.*

---



---

**Caution**     *When cleaning the orifice, take care not to damage it. The orifice is thin and fragile.*

---

To clean the front of the orifice:

1. Remove the Ion Source.




---

**WARNING**     *The Interface region is heated and the Curtain Plate can be hot to the touch. Once the Ion Source is removed, the Interface heater is automatically shut off and the Curtain Plate will begin to cool down.*

---

2. Remove the Curtain Plate.

---

**Note**     *When cleaning the Interface components, always wear powder-free latex gloves, and keep the components and Vacuum Chamber free of dust.*

---

3. Slightly dampen a poly swab with 2-propanol or methanol and gently wipe the Orifice Plate around and over the orifice. You may need to use a small amount of water to remove any contaminants that are not soluble in organic solvents. Ensure that the poly swab is not too damp. Any excessive solvent can enter the Vacuum Chamber and cause the pressure to rise above the instrument reset set point. If this does occur, allow the instrument to pump down to the operating pressure before proceeding with further cleaning or instrument use.
4. Remount the Curtain Plate.
5. Replace the Ion Source.

The back of the Orifice, Ring Electrode, and Skimmer can be cleaned by shutting down and venting the instrument, then removing the Orifice/Skimmer module from the Vacuum Interface.

---

## Removing and Replacing the Orifice/Skimmer Module

---

|                |                                                                                                                                                                                                                                                         |
|----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Caution</b> | <b><i>Keep the replacement Skimmer clean. Dust, dirt, even fingerprints will contribute to chemical background noise. Do not open the replacement Skimmer until just prior to installation. Always wear latex gloves when handling the Skimmer.</i></b> |
|----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

---

|                |                                                                                                                               |
|----------------|-------------------------------------------------------------------------------------------------------------------------------|
| <b>Caution</b> | <b><i>Handle the Skimmer tip with care. The tip is fragile. Damage to the tip will affect the instrument's operation.</i></b> |
|----------------|-------------------------------------------------------------------------------------------------------------------------------|

---

To remove the Orifice/Skimmer module:

1. Shut down the instrument.
2. Shut off all gas supplies.
3. With a 3.0 mm Allen key, remove the three hex-head screws that attach the Curtain Plate and the Orifice/Skimmer module to the Vacuum Interface.
4. Disconnect the clamp connecting the interface vacuum line to the vacuum flange (see the Vacuum Hook-up Schematic figure).
5. Unhook the latch that closes the Interface housing to the Vacuum Chamber, and swing open the Vacuum Interface.
6. To remove Curtain Plate and Orifice/Skimmer module, pull it perpendicularly from the Interface. (see the Vacuum Interface Assembly figure).

|             |                                                                                                                         |
|-------------|-------------------------------------------------------------------------------------------------------------------------|
| <b>Note</b> | <b><i>If the Curtain Plate/Orifice/Skimmer module stick to the Interface collar, gently pull on the components.</i></b> |
|-------------|-------------------------------------------------------------------------------------------------------------------------|

---

To clean the back of the Orifice, Focusing Ring, and Skimmer:

1. Gently separate the Orifice Plate from the Skimmer.

|             |                                                                                                                                                                                   |
|-------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Note</b> | <b><i>If the Orifice/Skimmer module is tight and cannot be separated manually, insert a small screwdriver between the two plates and gently pry the Skimmer to loosen it.</i></b> |
|-------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

---

2. Clean the Skimmer with methanol and a clean dust-free wipe. Spray the Skimmer and Skimmer Plate with dry gas to evaporate the residual methanol and allow them to dry completely before reinstalling them.

---

|             |                                                                                                                                                                      |
|-------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>Note</i> | <i>Do not use cotton swabs in any of the cleaning procedures because they leave cotton fibres behind. Only use the poly swabs that are provided with instrument.</i> |
|-------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|

---

3. From the Skimmer (Vacuum Chamber) side of the Interface, gently clean the Focusing Ring and Orifice with a poly swab dampened with methanol. Take care not to damage the Orifice; it is very fragile.
4. Allow the methanol on the Orifice and the Focusing Ring to dry completely before re-assembling them.
5. Re-assemble the Orifice/Skimmer module by aligning the two plates such that the voltage connectors on the Orifice Plate pass through the corresponding holes in the Skimmer Plate. Press together.
6. Replace the cleaned Orifice/Skimmer module according to the next procedure.

To replace the Skimmer:

1. Place the Orifice/Skimmer module within the Interface Assembly aligning the voltage connectors on the module with the feedthroughs on the Vacuum Interface. (See the Vacuum Interface Assembly figure).
2. Replace and tighten the three hex-head screws.
3. Power up the instrument.

### **Cleaning Q0**

The high pressure entrance quadrupole (Q0) can become contaminated if the instrument is operated with a curtain gas setting that is too low or if the Ion Source sprays directly towards the Orifice. Symptoms of a contaminated Q0 include a dramatic loss in sensitivity (typically a factor of 5) and a decrease in ion peaks widths. For more information, refer to the *API 2000 Qualified Service Operator's Manual*.

To clean Q0:

1. Remove the Orifice/Skimmer module (see the procedure earlier in this chapter) to expose the front of Q0.
2. Gently clean Q0 from the front to the end with the provided poly swab dampened with methanol by carefully sliding it through the center of the four quadrupoles. Do not use excessive force when inserting the swab.

---

|             |                                                                                                                                                                              |
|-------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>Note</i> | <i>Do not use cotton swabs in any if the cleaning procedures because they may leave cotton fibres behind. Only use the poly swabs that are provided with the instrument.</i> |
|-------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

---

- 
3. Allow the methanol on Q0 to dry.
  4. Replace the Orifice/Skimmer module, and then power up the instrument.

### Removing and Replacing the Curtain Plate



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**WARNING**     *Using the overnight quit command before performing this procedure will allow you to remove the Ion Source. To ensure that high voltages are not applied, you will have to shut down the instrument completely. Windows NT and MAC users should choose Standby from the Acquire Menu.*

---

To remove the Curtain Plate:

1. Remove the Ion Source.
2. With a 3.0 mm Allen key, unscrew the three hex-head screws that attach the Curtain Plate to the Vacuum Interface.
3. To remove the Curtain Plate, pull it perpendicularly from the Vacuum Interface.

---

**Note**     *In some cases, the Curtain Plate may stick to the Teflon mounting collar. If this occurs, gently pull on the Curtain Plate.*

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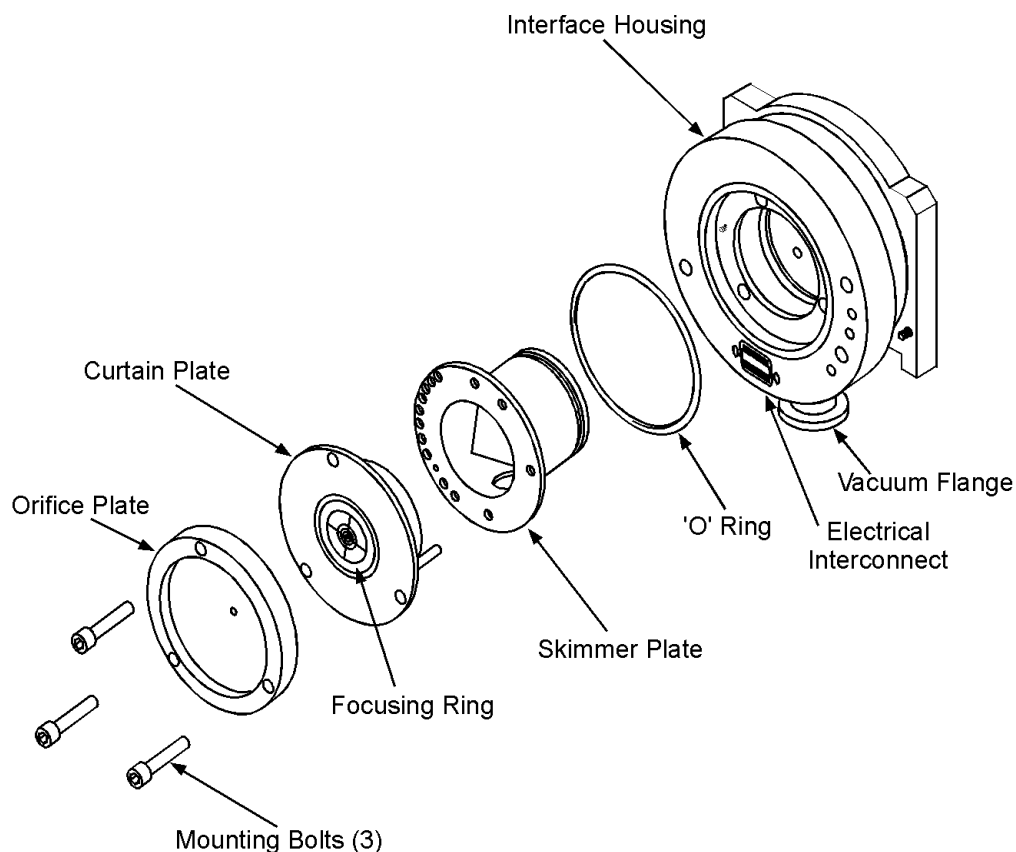


**Figure 3-5. Vacuum Interface Assembly**

To replace the Curtain Plate:

1. Place the Curtain Plate in position against the Teflon portion of the Vacuum Interface.
2. Replace and tighten the three hex-head screws.
3. Replace the Ion Source.

### **Disassembling the Vacuum Interface Assembly**

---

|                |                                                                                                                                                                                                                                             |
|----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Caution</b> | <b><i>Dust, dirt, even fingerprints will contribute to electrical background noise. Always wear powder-free latex gloves when handling the Interface components. Take the necessary precautions to keep them free of dust and dirt.</i></b> |
|----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

---

The Vacuum Interface Assembly comes as a Field Replacement Unit (FRU) and can be replaced in the field as a complete unit.

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### To remove the Vacuum Interface Assembly:

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**Note**      *Before performing this procedure, you should wait 15 - 20 minutes to allow the Interface time to cool down.*

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1. Shut down the instrument.
2. Using a 2.5 mm Allen key, unscrew the three hex-head screws that secure it in place. See the figure below.

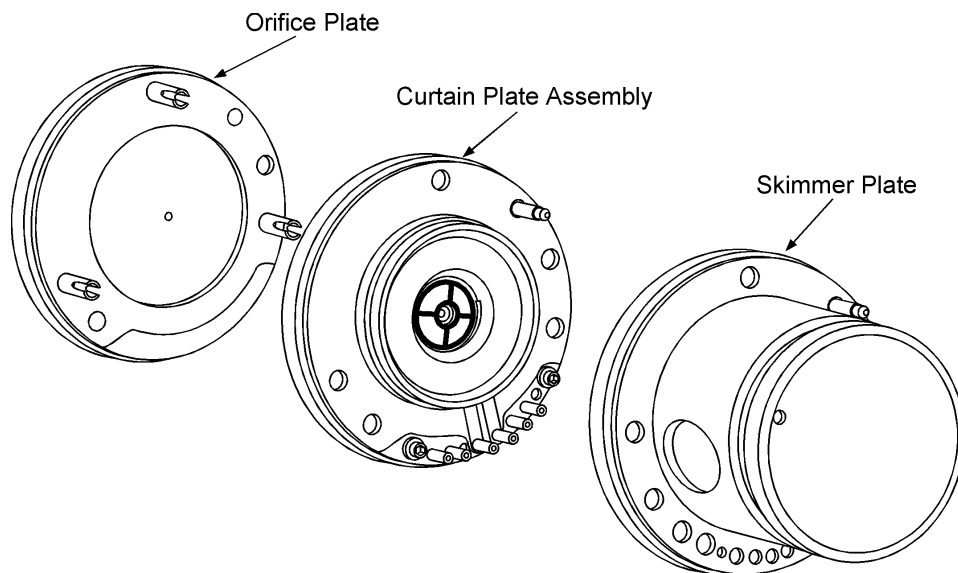


**Figure 3-6. Skimmer Plate/Curtain Assembly**

3. Using a small screwdriver, remove the Curtain Plate by prying between the Teflon piece. Gently remove the Curtain Plate from the Interface Assembly.

---

**Caution**      *When removing the Curtain Plate, never insert the screwdriver in the region of the PCB interlock. This can damage the Vacuum Interface.*

---

### Re-Assembling the Vacuum Interface

If the rear Retaining Ring and Skimmer Plate remain intact, skip this portion of the assembly procedure.

1. Ensure that the O-ring is in position around the Skimmer plate. See the Vacuum Interface Assembly figure.

2. Position the Skimmer in the Skimmer plate, making sure that the O-ring is in place around the Skimmer flange.
3. Ensure that the gas feedthroughs and the Interlock feedthroughs are aligned with the connections on the bottom of the Interface housing.

---

**Caution**      *Be careful not to damage the tip of the Skimmer. It is fragile.*

---

4. Ensure that the Skimmer does not touch Q0.
5. Rock the Skimmer back and forth until it is in place. Push down firmly to ensure that it is seated flush with the O-ring.

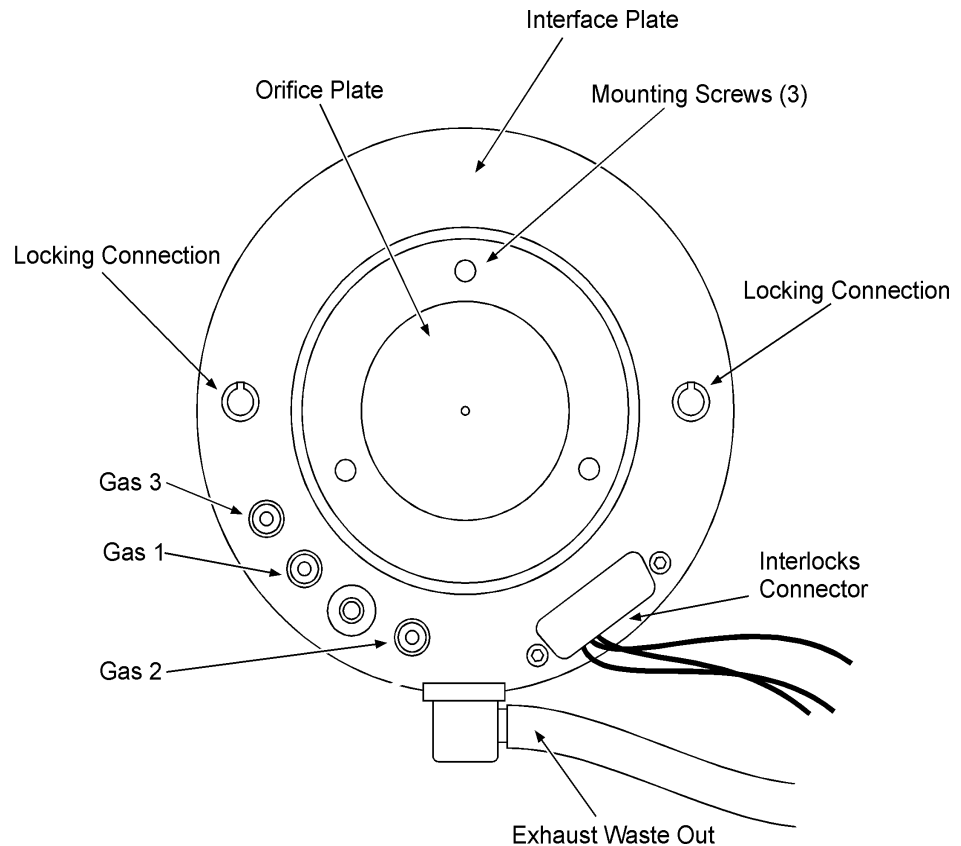


**Figure 3-7. Interface Plate - Rear View**

6. Align the Curtain Plate with the holes for the high power voltage, the feedthroughs, and the three connectors. See the figure above.
7. Push the connectors until they are flush.
8. Using a 3.0 mm Allen key, slightly tighten all three screws first, then

---

tighten one at a time.

9. With a multimeter, confirm the following using the Vacuum Interface Hook-up Schematic figure as a reference:
  - That there is electrical continuity between the Curtain Plate and the connector.
  - That there is electrical continuity between the Focusing Ring and the connector.
  - That there is electrical continuity between the Orifice and the connector.
  - That the Focusing Ring and the Orifice Plate are electrically isolated. There should be no electrical leakage between the Ring and the Orifice Plate.

## 4 Vacuum Chamber

---

### 4.1 Overview

The Vacuum Chamber is a single aluminum extrusion that houses the four quadrupole rod sets, most of the ion optics, the Collision Cell, and the Ion Detector (ETP). The quadrupoles, Collision Cell, and associated ion optics are assembled on the Mass Filter Rail and inserted into the Vacuum Chamber as a single unit (See the API 2000 Mass Filter Rail figure). The Ion Detector, which is housed in the ETP module, is installed inside the Vacuum Chamber after the Mass Filter is in position.

A seal formed by the Front Bulkhead on the Mass Filter Rail divides the Vacuum Chamber into two distinct regions. The Q0 Region contains the Q0 rod set. It is located between the Vacuum Interface and the Front Bulkhead on the Mass Filter Rail. This region is maintained at  $8 \times 10^{-3}$  torr by the split DI220 LPS Turbo Pump.

The High Vacuum Region contains the three remaining rod sets and the associated ion optics. It is maintained at about  $1 \times 10^{-5}$  torr by the split DI220 LPS Turbo Pump. The Q2 quadrupole rod set is contained in the Collision Cell that forms part of the High Vacuum Region (see the *Collision Cell* section in this chapter). The Q1 and Q3 mass filter quadrupoles are located on either side of the Collision Cell and are open for free pumping by the split DI220 LPS Turbo Pump.

---

|             |                                                                                                                                                                                                           |
|-------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>Note</i> | <i>The Vacuum Chamber is safely interlocked such that if the pressure inside the High Vacuum Region reaches <math>1 \times 10^{-4}</math> torr or greater, all ion path voltages will be set to zero.</i> |
|-------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

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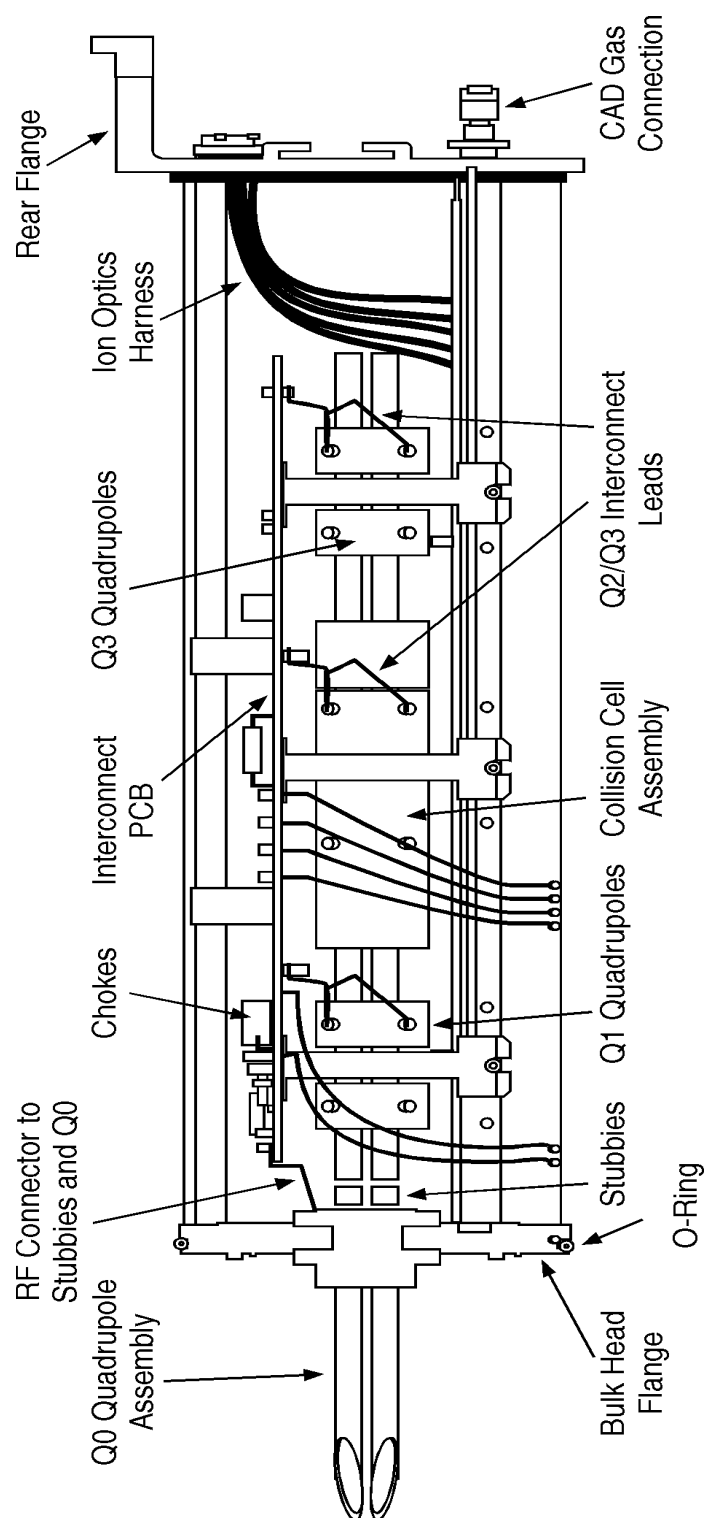


Figure 4-1. API 2000 Mass Filter Rail

---

### 4.1.1 Mass Filter Rail

The quadrupole rod sets and ion optics are installed, aligned, and wired on the Mass Filter Rail before the rail is inserted into the Vacuum Chamber. The front end of the Mass Filter Rail is supported by the Front Bulkhead. The other end of the Mass Filter Rail is bolted to the rear flange that seals the detector end of the Vacuum Chamber. The Front Bulkhead can be accessed through the Vacuum Interface to easily remove the Mass Filter Rail.

All gas lines and internal wires are routed along the Mass Filter Rail. The external ion optic and the gas connections are made through vacuum connectors on the rear flange.

Vacuum Feedthroughs are used to connect the RF and DC voltages for the Q1 and Q3 mass filter quadrupoles through the bottom of the Vacuum Chamber. The leads are connected after the Mass Filter Rail has been installed.

---

|                |                                                                                                            |
|----------------|------------------------------------------------------------------------------------------------------------|
| <b>Caution</b> | <b><i>The Mass Filter Rail cannot be removed unless the Vacuum Feedthrough leads are disconnected.</i></b> |
|----------------|------------------------------------------------------------------------------------------------------------|

---

For more information on vacuum feedthroughs, refer to the *Vacuum Feedthroughs* section in this chapter.

### 4.1.2 Quadrupoles

The four quadrupoles are mounted on the Mass Filter Rail inside the Vacuum Chamber. Q1 and Q3 are mass filters that selectively filter ions based on their mass-to-charge ratio ( $m/z$ ). Q0 and Q2 are RF-only quadrupoles that have no filtering effect.

---

### 4.1.3 Mass Filters (Q1 and Q3)

In the API 2000 instrument, both Q1 and Q3 are quadrupole mass filters. A quadrupole mass filter consists of four cylindrical electrodes (rods) to which precise DC and RF voltages are applied. The Q1 and Q3 rods are enclosed by ceramic collars and positioned accurately on the Mass Filter Rail using the locating pins.

In a paper entitled, "Energetic Ion Mass Analysis Using a Radio-Frequency Quadrupole Filter", published in Rev. Sci. Instrum. 49(6), June 1978, S.S. Medley presents an excellent and concise review of the more salient features of quadrupole mass filters. The following excerpt has been taken from this article:

*A quadrupole mass filter is constructed ideally of four electrically conducting parallel hyperbolic cylindrical surfaces. For convenient fabrication, most mass filters are constructed with poles of circular cross section (see the Mechanical and Electrical Configuration of a Quadrupole Mass Filter figure). The best approximation to a hyperbolic field using cylindrical poles is to space them so that  $r = 1.16r_0$ , where  $r$  is the pole radius and  $r_0$  is the radius of the inscribed circle which is tangent to the four pole edges. Opposite electrodes of the filter are electrically connected. To one pair is applied a potential of  $U + V \cos \omega t$ , where  $U$  is a DC voltage and  $V$  is the peak amplitude of an RF voltage at frequency  $\omega = 2\pi f$ . To the other pair is applied a potential of the same amplitude, but the DC voltage is of opposite polarity and the RF voltage is shifted in phase by  $180^\circ$ .*

*Optimum performance of the quadrupole filter depends on precise DC and RF fields along the entire length ( $L$ ) of the rod assembly which requires both high mechanical and electrical stability of the applied voltages. The fractional dimensional accuracy needed is given by  $1/4(\Delta M/M)$  and required electrical stability is  $1/2(\Delta M/M)$ , where  $M/\Delta M$  is the mass resolution of the filter. The mass resolution is controlled by the ratio  $U/V$  of the DC to RF potentials according to the equation:*

$$M/\Delta M = \frac{0.126}{0.168 - \langle U/V \rangle}$$

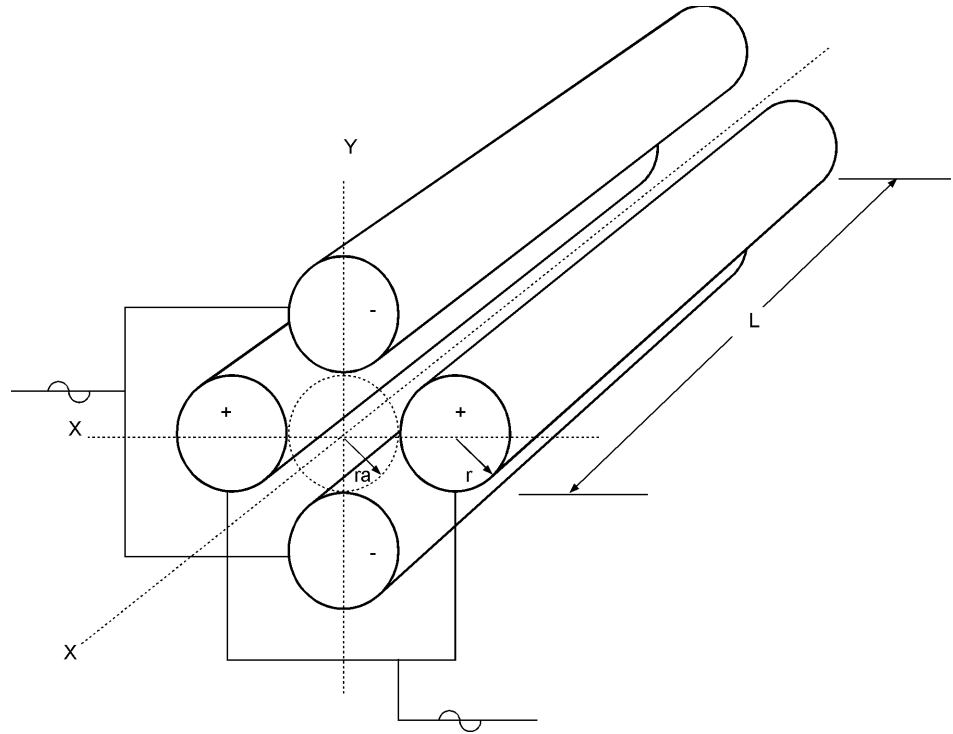


**Figure 4-2. Mechanical and Electrical Configuration of a Quadrupole Mass Filter**

*Local radial variations in the pole's dimensions are not as detrimental to quadrupole performance as extended axial errors, since these errors conceivably may have a cumulative effect. Ions injected parallel to the Z axis of the quadrupole undergo transverse oscillations caused by the perpendicular DC and RF voltages applied to the electrodes. The ion trajectories are described by Mathieu equations, the solutions of which contain either an exponential or an oscillatory factor, depending on the charge to mass ratio ( $e/M$ ) of the ion.*

*With proper selection of  $U$  and  $V$ , ions of a given  $e/M$  will have stable trajectories, that is, they will oscillate about the Z-axis and ultimately emerge from the opposite end of the mass filter. Ion with other values of  $e/M$  will have unstable oscillations which increase in amplitude until they collide with the electrodes, thus being neutralized and removed from the injected ion beam.*

---

Q1 and Q3 have very high mechanical precision necessary for achieving high transmission and high resolution. The normal trade-off between high ion transmission and narrow peak width must be optimized for each particular application. Q1 and Q3 normally operate at a constant mass width ( $\Delta M$ ) that is independent of the ion mass ( $M$ ). Hence, the resolution ( $M/\Delta M$ ) in this mode of operation is directly proportional to the mass being observed.

Q3 is also capable of being operated in “total ion mode” in which only RF voltage is applied to the quadrupole rods (other terms are “RF-only mode” and AC-only mode”). This essentially allows ions of all masses present in Q3 to be transmitted to the Ion Detector.

#### 4.1.4 RF-Only Quadrupole (Q0 and Q2) and Stubbies

An RF-only quadrupole is similar in construction to a quadrupole mass filter, but is only capable of being operated in total ion mode (only RF voltage is applied to the rods). In the API system, both Q0 and Q2 are RF-only quadrupoles.

Q0 is mounted in the Front Bulkhead of the Mass Filter Rail. The Q0 rod set focuses and transfers ions from the Vacuum Interface through the interquad lens Q1 into the Stubbies and in the High Vacuum Region. The Stubbies prefilter and transfer the ions into the Q1 mass filter. To optimize ion transfer, both Q0 and the Stubbies are electrically connected to the Q1 RF voltage. The RF voltage applied to Q0 and the Stubbies is a consistent fraction of the RF voltage applied to Q1.

Q2 is housed inside the Collision Cell that is mounted between Q1 and Q3 on the Mass Filter Rail. It transmits ions through the Collision Cell into Q3. Similar to Q0, the Q2 RF voltage is capacitively coupled to the Q3 RF voltage. The Q3 RF voltage is capacitively coupled to the Q2 voltage so that the Q2 RF voltage is ramped in a constant ratio with respect to that of Q3. Q2 is an integral part of the Collision Cell. For more information on the *Collision Cell*, refer to the Collision Cell section in this chapter.

#### 4.1.5 Vacuum Feedthroughs

The amplified RF and DC voltages for Q1 and Q3 are connected through the bottom of the Vacuum Chamber via the Vacuum Feedthroughs (see the Vacuum Feedthrough figure). There are four feedthroughs: two for Q1 and two for Q3. Each feedthrough carries the combined RF and DC voltages for one pair of opposing quadrupole rods.

The feedthroughs are installed through punch-outs in the tops of the Q1 and Q3 Coil Boxes into designated holes in the bottom of the Vacuum Chamber. One end of each feedthrough lead is connected to the respective

---

Interconnect Circuit Board inside the Vacuum Chamber; the other end to a sleeve in the respective Coil Box.

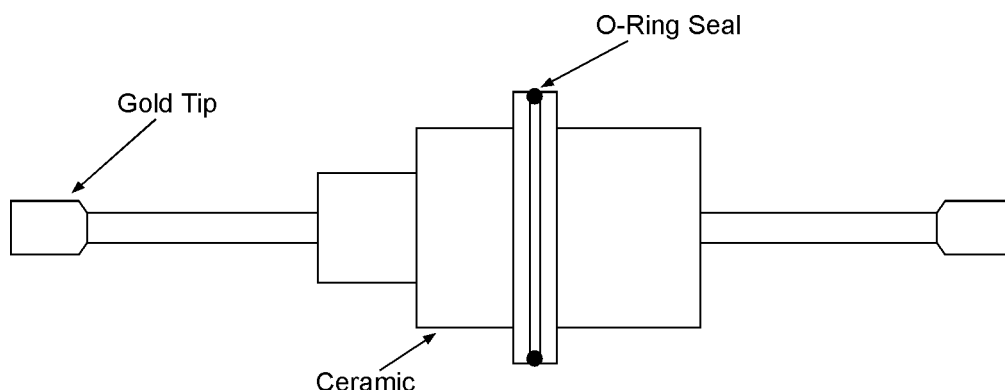


**Figure 4-3. Vacuum Feedthrough**

#### 4.1.6 Collision Cell

The Collision Cell is a ceramic housing pressurized with Curtain Gas. The housing contains Q2 and is closed at either end by interquad lenses IQ1 and IQ2.

Ions enter Q2 through IQ2 and collide with the Curtain Gas molecules in the cell. The collisions provide the energy needed to dissociate precursor ions into fragment ions. All ions in the Collision Cell are transferred to Q3 where the precursor or fragment ions can be selectively filtered and transferred to the ETP for counting.

Curtain Gas is fed through a vacuum fitting on the end of the flange of the Vacuum Chamber. The Curtain Gas line is then routed along the Mass Filter Rail and fed through a hollow locating pin in the top of the Collision Cell.

Since the degree of fragmentation is a function of Curtain Gas thickness (CGT), the CGT must be controlled. This is accomplished by controlling the flow of Curtain Gas that has been re-directed from the Differentially Pumped Interface and fed through a gas flow controller to the Collision Cell. The gas flow is set by the operator from the Applications Computer. For more information on Gas Flow Control, refer to the *Vacuum Control System* section in this manual.

#### 4.1.7 Ion Optics

The API 2000 ion optics are designed to help guide and focus the sample ions through the mass filters and deliver these selected ions to the Ion Detector. Voltage potentials are applied to the ion optics by the operator at

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the Applications Computer and can be varied for different sample and application requirements.

The ion optics are illustrated in the API 2000 Ion Optics Path figure and consist of the following:

- Curtain Plate
- Orifice Plate (OR)
- Focusing Ring (RNG)
- Stubbies (ST)
- Interquad Lenses (IQ1, IQ2, IQ3)
- Exit Lens (EX)
- Deflector (DF)

A list of ion optics standard voltage settings is provided in the following table.

The Curtain Plate, Orifice Plate, and Focusing Ring are part of the Vacuum Interface and have been discussed previously in the *Vacuum Interface* section in this manual.

The Stubbies, Interquad Lenses, and the Exit Lens are mounted on the Mass Filter Rail. The Stubbies help transfer the ions from the Q0 region to the Q1 mass filter in the High Vacuum Region. This lens is actually a shortened version of an RF-only quadrupole (see the *RF-Only Quadrupole (Q0 and Q2) and Stubbies* section described earlier in this chapter). The Interquad Lenses help the transmission of ions into the respective quadrupoles, the Deflector helps to improve the collection efficiency of the Ion Detector.

The Deflector, Ion Detector (ETP), and support electronics are contained in a separate module that attaches to the front of the Vacuum Chamber at the detector end of the instrument. For more information, refer to the *Ion Detector (ETP) and Signal Handling* section in this chapter.

**Table 4-1. Ion Optics Standard Voltage Settings**

| Component                                                                                                          | ID  | *MS          | *MS/MS       | *Range       |
|--------------------------------------------------------------------------------------------------------------------|-----|--------------|--------------|--------------|
| Ion Source                                                                                                         | IS  | +5 kV        | +5 kV        | 0 to 8 kV    |
| Curtain Plate                                                                                                      | **  | +1 kV        | +1 kV        | +1 kV        |
| Orifice Plate                                                                                                      | OR  | +35 kV       | +35 kV       | +0 to +200V  |
| Focusing Ring                                                                                                      | RNG | +300 kV      | +300 kV      | +0 to +400V  |
| Quadrupole 0                                                                                                       | Q0  | -10V         | 10V          | +0 to -17V   |
| Interquad Lens 1                                                                                                   | IQ1 | -12.0V       | +12V         | +0 to -40V   |
| Stubbies                                                                                                           | ST  | -15V         | -15V         | +0 to -40V   |
| Quadrupole 1                                                                                                       | Q1  | -12V         | -12V         | +0 to -20V   |
| Interquad Lens 2                                                                                                   | IQ2 | -25V         | -25V         | +0 to -200V  |
| Quadrupole 2                                                                                                       | Q2  | -25V         | -25V         | +0 to -200V  |
| Interquad Lens 3                                                                                                   | IQ3 | -100V        | -50V         | +0 to -200V  |
| Quadrupole 3                                                                                                       | Q3  | -100V        | -26 to -28V  | +0 to -200V  |
| Exit Lens                                                                                                          | EX  | +0V          | -0V          | +0V          |
| Deflector                                                                                                          | DF  | 0V           | 0V           | -400 to 0V   |
| Ion Detector                                                                                                       | ETP | as optimized | as optimized | +0 to -3200V |
| *Values are for positive ion mode. For negative ion mode, the voltages are the same, but the polarity is reversed. |     |              |              |              |
| **The Curtain Plate's voltage is not controlled by the software.                                                   |     |              |              |              |

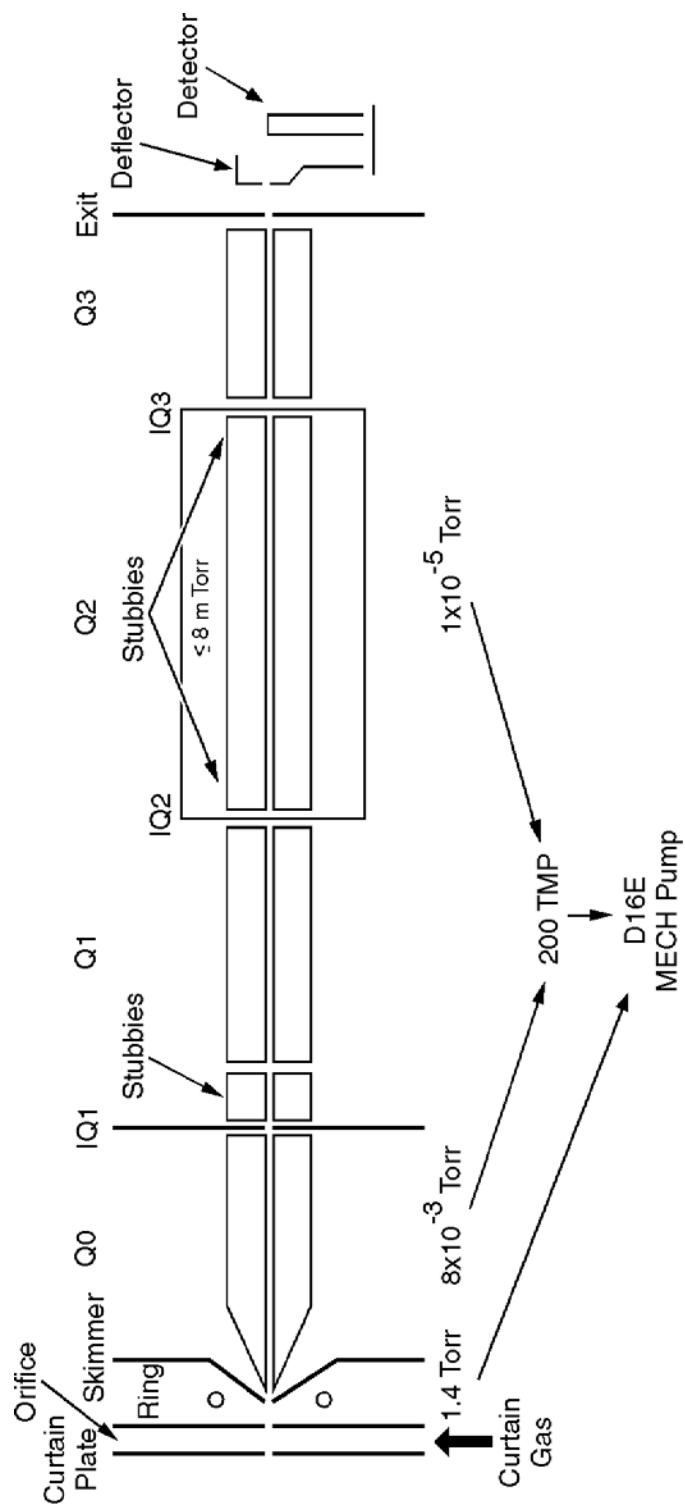


Figure 4-4. API 2000 Ion Optics Path

### 4.1.8 Ion Detector (ETP) and Signal Handling

The figure below shows the makeup of the ETP Unit.

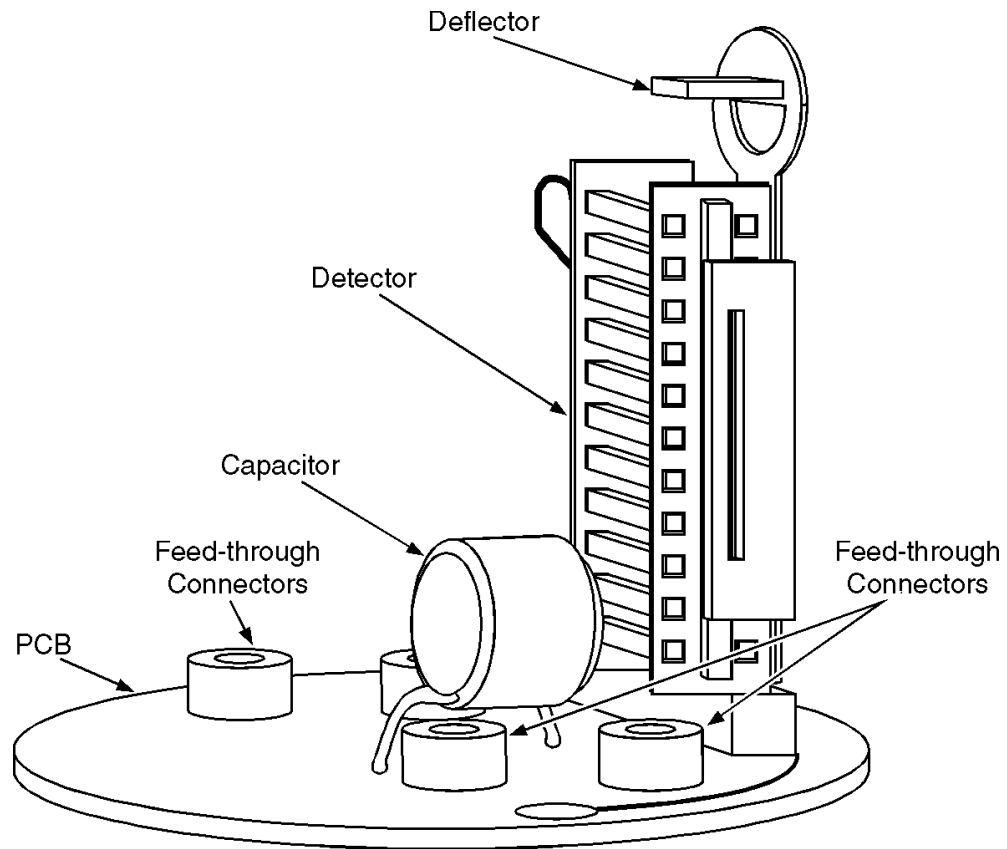


**Figure 4-5. ETP Unit**

The table below shows ETP voltage and its limits.

**Table 4-2. ETP Voltage and Limitations**

| Mode     | DET Voltage | Limits for DET- Voltage | Limits for Bias Voltage |
|----------|-------------|-------------------------|-------------------------|
| Positive | 500V        | -6800 to -5500V         | $\leq +1000V$           |
| Positive | 2000V       | -6800 to -5500V         | +1600V to +2500V        |
| Positive | 3000V       | -6800 to -5500V         | +2600V to +3600V        |
| Negative | 500V        | +3600 to +4400V         | $\leq +1000V$           |
| Negative | 2000V       | +3600 to +4400V         | +1600V to +2500V        |
| Negative | 3000V       | +3600 to +4400V         | +2600V to +3600V        |

---

## ETP and the Deflector

### ETP- Voltage

The ETP- voltage is fixed depending on the polarity of the ions that you are analyzing. For positive ions, the voltage ranges from -6800V to -5500V; for negative ions, the voltage ranges from +4000V to +3600V. This voltage comes from the High Voltage Power Supply Board. The network divider is used to supply the low voltage test point for the ETP- voltage. By using 1000 M $\Omega$  (R7) and 1.1M $\Omega$  (R6), the divider ratio is set to 1000:1 approximately. This enables an accurate test point when you are running diagnostics. You can also reduce the noise by over 35db on the signal due to rippling on the ETP+ terminal by adding a RC filter (R3//C3) in series.

### ETP+ Voltage

The potential gradient is created with a second ETP voltage and the bias voltage. The bias voltage applied to the end of ETP is typically set between 2000 to 3000 volts. Therefore, the actual voltage applied to the end of the ETP is the combined ETP- voltage and bias voltage. The bias detector voltages are also supplied from the HV Power Supply board. The network divider is used to supply the low voltage test point for the ETP+ voltage. By using 1000 M $\Omega$  (R4) and 1.1M $\Omega$  (R1), the divider ratio is set to 1000:1 approximately. This enables an accurate test point when you are running diagnostics.

### Deflector Voltage

The Deflector voltage is supplied by the Lens Power Supply Board. Its varies from -400 to +400 volts and can be set by the operator at the Applications Computer. The gas resistor (DS1) acts as a Surge Voltage Protector for this circuit.

### Signal Handling Board

The Signal Handling Board serves two distinct functions:

- Converts low-level Ion Detector output pulses to digital levels that can be transmitted to the System Controller.
- Acts as a conduit for the ETP's high voltages (power).

In pulse-counting-mode, the ETP responds to each strike by producing a current pulse that flows through the connector socket (J1). This current pulse then flows through a 511 ohm resistor (R1) producing a negative, bell-shaped pulse (see the next figure).

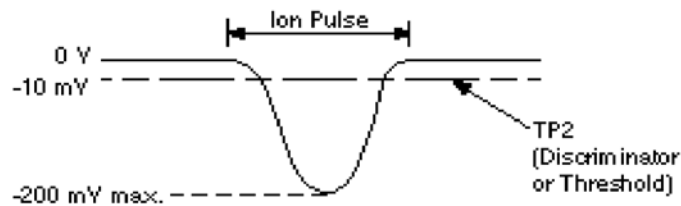


**Figure 4-6. Response of the Signal Handling Circuit to Pulse Input**

The amplitude of the pulse can vary up to about 200mV depending on the ETP's condition, bias voltage setting and other normal statistical variations. The operational amplifier U1 is a precision voltage-feedback amplifier that has a fast settling time, excellent differential gain and differential phase performance. The non-inverting gain of U1 is set to 21 V/V via resistors R5 and R9. Resistor R7 and diodes D1 and D2 are only used to protect U1 from potential transient conditions. The low-frequency gain of U1 is unity to reduce the effect of DC level shift due to AC coupling of the input signal. R15 and C5 are used for the +5V power supply filtering, whereas R12 and C4 are used for the -5V power supply filtering.

The amplified pulse is conducted to the positive input of a high-speed comparator (U2), where it is compared to a discriminator voltage applied to the negative input of the comparator. The discriminator voltage (threshold) is the minimum pulse strength for which the signal handling circuitry will register an ion strike. The combination of the potentiometer R2, resistors R3, R4, and capacitor C1 gives a stable negative DC discriminator voltage. Using R2, this voltage can be adjusted between 0 and -200mV and can be measured between TP2 (ground) and TP1. Resistors R13, R11 and capacitor C3 are specifically used to introduce hysteresis at U2 by temporarily injecting some positive feedback each time a pulse crosses the discriminator level. This ensures a minimum output pulse width for the counting circuit.

The non-inverted TTL output of the comparator U2 is passed to the System Controller via a driver in U5. This driver converts its TTL input to balance pseudo ECL levels. Pseudo ECL levels are the ECL levels shifted by 5V to run on a single +5V power supply.

The "test signal" function helps verify the ion counting circuitry. The test signal is a pseudo ETP output signal that originates at the System Controller. When it is enabled, it transmits a pulse-like test signal to the Signal Handling Board. This signal input is received and converted to TTL levels by a receiver in U5. It is then fed to the positive input of the comparator U2 via R8 and C13. If the signal handling circuitry is functioning properly, the Applications Computer produces scan results with an ion intensity equal to the frequency of the test signal.

---

## 4.2 ETP Service Procedures

### Removing the ETP Module



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**WARNING**     **BIOHAZARDOUS MATERIAL** *Do not dispose of system components or subassemblies, including computer parts, in municipal waste. Dispose of replaced components and instruments according to established waste electrical equipment procedures.*

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1. Shut down and vent the Instrument.
2. Remove the console power cord from the right-hand side of the bulkhead behind the instrument.



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**WARNING**     **HIGH VOLTAGE.** *Follow the shut down procedure to ensure that the voltage is disconnected.*

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**Caution**     *The ETP is fragile. Use care when installing the new ETP assembly. Do not allow dust or dirt on the ETP assembly or the vacuum feedthroughs. Contamination can cause electrical noise.*

---

3. Open the ETP Cover.
4. Disconnect the ETP Signal and Control Panel Cable from the Signal Handling Board.

---

**Caution**     *Do not disconnect the ETP cable while voltage is applied to ETP because it can damage the Signal Handling Board and the System Controller.*

---

5. Remove the two hex-head screws that connect the ETP housing to the Vacuum Chamber.
6. Slide the ETP housing straight out of the Vacuum Chamber until the guide arm clears the rear flange.
7. Place the ETP assembly carefully on a flat work space with the Signal Handling Guard flat on the table.

### Replacing the ETP Module

1. Remove the ETP Module and place it on a clean work surface.

- 
2. With a 3 mm Allen Key, remove the hex-head screw and associated lock washer connecting the ETP mounting board to the stand off on the vacuum flange. See the ETP Replacement figure.
  3. Pull the ETP mounting board to release it from the four feedthroughs.
  4. Without touching the ETP, attach a new ETP assembly to the feedthroughs. Firmly push the ETP mounting board against the feedthroughs to ensure a sound connection. Gently push the ETP PCB back towards the Guide Arm.
  5. Replace the hex-head screws that secure the ETP mounting board to the vacuum flange.
  6. Install the ETP module by sliding the ETP housing straight into the Vacuum Chamber.
  7. Replace the two hex-head screws that connect the ETP housing to the Vacuum Chamber.
  8. Connect the ETP signal and the Control Panel Cable to the Signal Handling Board.

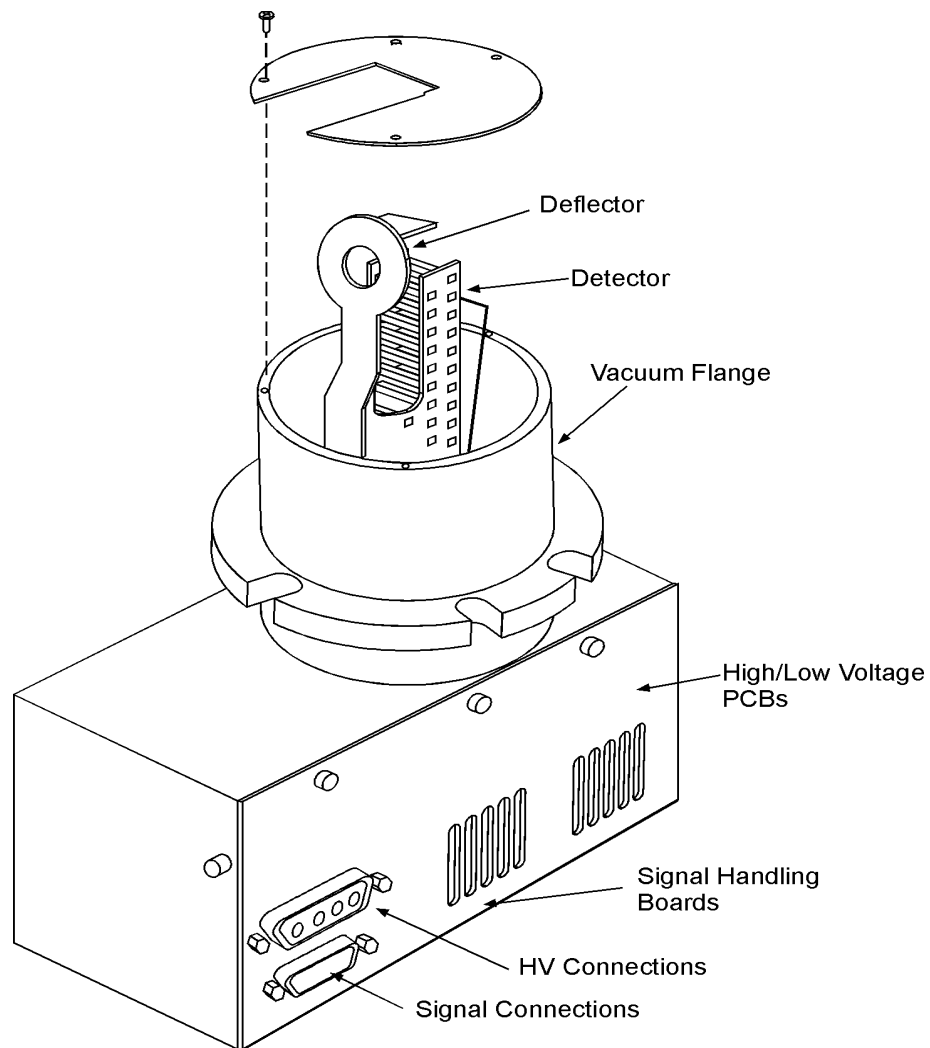


Figure 4-7. ETP Replacement

---

## Replacing the Signal Handling Board

---



**WARNING**     **BIOHAZARDOUS MATERIAL** *Do not dispose of system components or subassemblies, including computer parts, in municipal waste. Dispose of replaced components and instruments according to established waste electrical equipment procedures.*

---

The Signal Handling Board can be replaced with the ETP Module installed in the Vacuum Chamber.



**WARNING**     *To prevent exposure to high voltage ensure that the instrument is off and the power is disconnected before opening the ETP Cover.*

---

**Caution**     *Do not disconnect the ETP cable while the voltage is applied to ETP because it can damage the Signal Handling Board.*

---

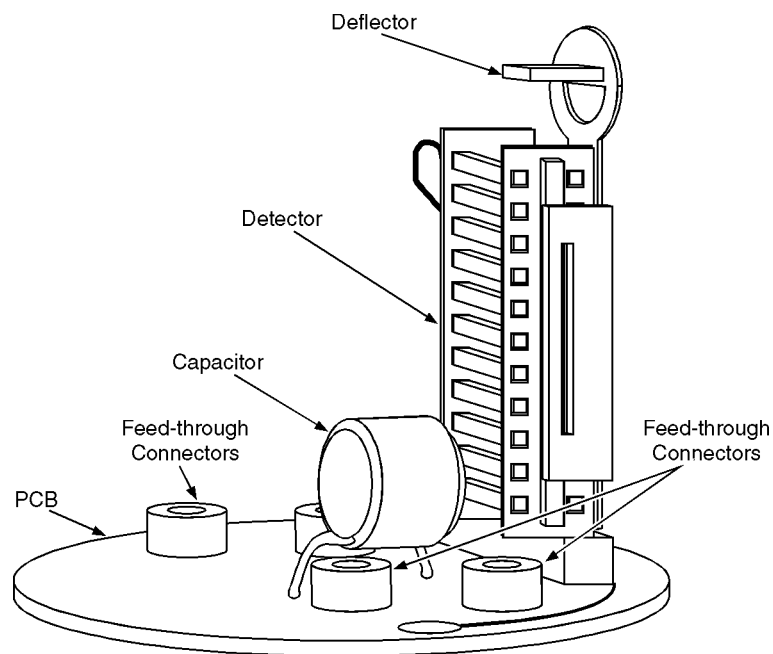


Figure 4-8. ETP Module Assembly

## Installing the ETP Module

- 
1. Slide the ETP assembly into position. Make certain that the O-ring is properly installed around the vacuum flange.
  2. Re-connect the ETP Signal and Control Panel Cable to the Signal Handling Board.
  3. Secure the assembly by replacing the two hex-head screws with the flat washers that connect the ETP vacuum flange to the Vacuum Chamber.

---

## 4.3 Mass Filter Rail Service Procedures

When servicing the instrument, removing the Mass Filter Rail is always a last resort. It is a rare occurrence for the ion optics to be the cause of a malfunction in an operational instrument. Remove the Mass Filter Rail only on advice from technical support personnel after exhausting all other possible causes of instrument malfunction.

The Mass Filter Rail slides from the rear of the Vacuum Chamber as a complete assembly. The Q1 and Q3 feedthroughs and the ETP Module must be removed before the Rail can slide from the Vacuum Chamber.

---

|                |                                                                                                                                                                                              |
|----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Caution</b> | <b><i>The Mass Filter Rail houses the fragile and sensitively aligned ion optics. Handle the rail with care. Keep the rail clean and wear powder-free latex gloves when handling it.</i></b> |
|----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

---



---

|             |                                                                            |
|-------------|----------------------------------------------------------------------------|
| <b>Note</b> | <i>If ions can be detected there is no reason to remove the mass rail.</i> |
|-------------|----------------------------------------------------------------------------|

---

### Removing the Mass Filter Rail

The Mass Filter Rail, the Q2 and the Q0 AC rod assembly are designed to be Field Replaceable Units (FRUs). Do not attempt to repair them in the field. Return the replaced assemblies to the factory for repair.

The Mass Filter Rail is dimensionally critical. The quadrupole support pins, and locating pins are factory aligned. Do not attempt to re-position them.

1. Shut down the instrument.
2. Remove all instrument covers.
3. Remove the Ion Source and set it aside.
4. Disconnect all gas connections and the ion optic connection, and allow the Vacuum Chamber to vent.
5. Remove Q1 and the Q3 Coil Box covers.

In both Q1 and Q3 Coil Boxes, there are two vacuum feedthroughs that must be removed before the Mass Filter Rail can slide from the Vacuum Chamber.

6. The procedure to disconnect the feedthroughs is the same for both the Q1 and Q3 coil boxes. For more information on the Coil Boxes, refer to the *Quadrupole Power Supply (QPS)* section in this manual.
7. Unlatch the feedthrough latch locking mechanism to the feedthrough housing. See the next figure.
8. Slide out the silver plate.

9. Gently pull the front feedthrough out of the Vacuum Chamber, and maneuver them out of the coil box.
10. Repeat steps 8 and 9 to remove the second feedthrough which is directly behind the first.

---

**Caution**      *The vacuum feedthroughs are sensitive to contamination. Always wear powder-free latex gloves when handling the feedthroughs and place them in a plastic bag immediately after removal to ensure they remain clean.*

---

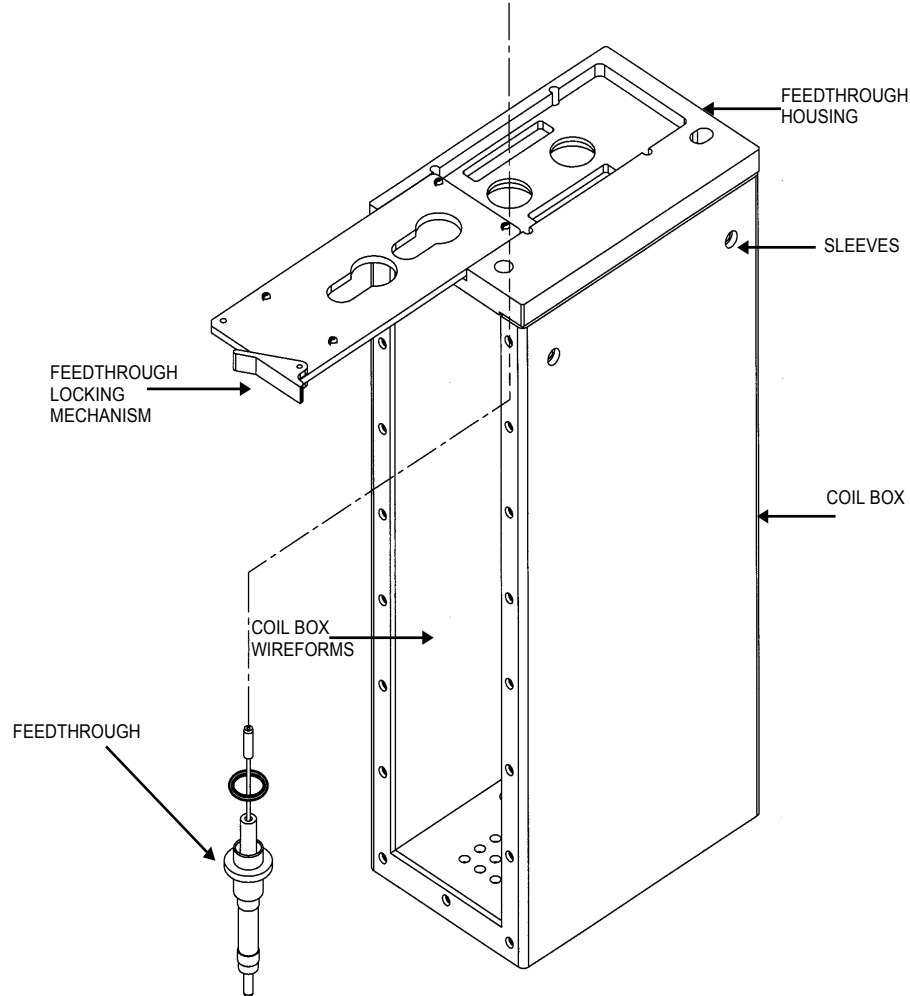


**Figure 4-9. Feedthrough Installation Schematic**

- 
11. Repeat steps 7 to 10 to remove the two feedthroughs in the other Coil Box.
  12. Remove the ETP Module.
  13. Place the ETP Module on a clean surface and cover the ETP with a dust-free covering.

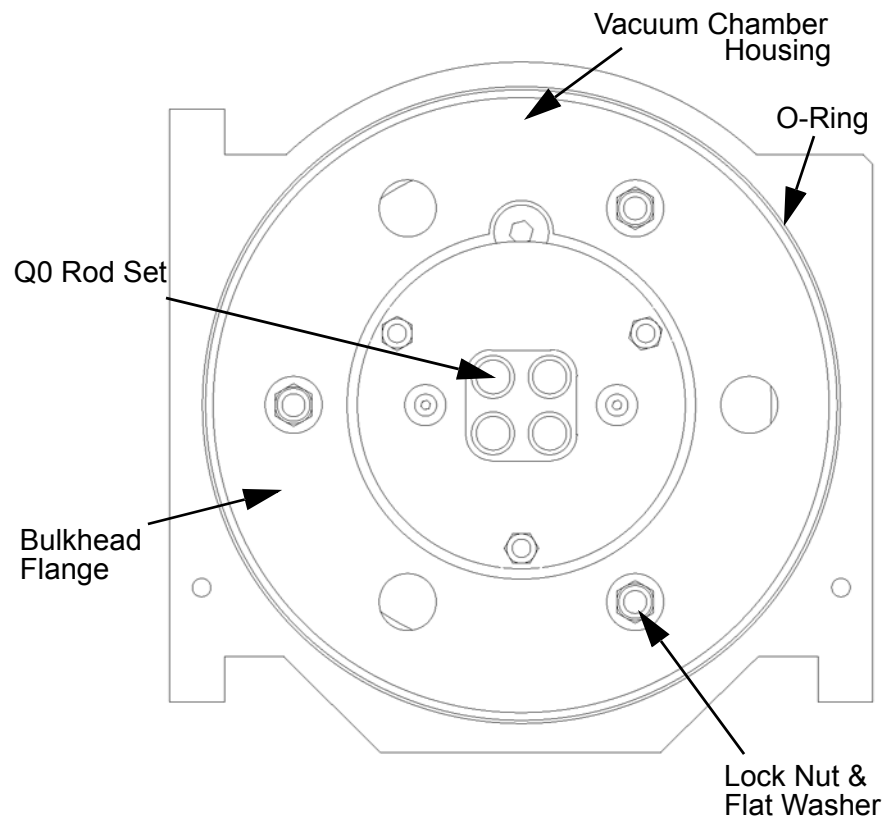


**Figure 4-10. Front Bulkhead**

14. Loosen, but do not remove, the three lock nuts on the front face of the bulkhead. See the figure above.

---

|             |                                                                                                                                                                                                                                                                           |
|-------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>Note</i> | <i>The nuts sandwich the O-ring between the Bulkhead Flange and the Bulkhead forcing it against the Vacuum Chamber housing to provide a vacuum seal. When the nuts are loosened the seal is released allowing the Front Bulkhead to slide through the Vacuum Chamber.</i> |
|-------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

---

15. Disconnect the ion optics harness from the rear flange.

- 
16. Using a 6.0 mm Allen key, remove the four lock nuts securing the rear flange to the studs mounted in the Vacuum Chamber housing.
  17. Firmly and evenly, pull on the flange handle and slide the Mass Filter Rail from the Vacuum Chamber. As the rear flange clears the mounting studs, twist the handle 180° while pulling. If the Mass Filter Rail does not slide, loosen the nuts on the Front Bulkhead until it slides through the Vacuum Chamber.
- 

---

**Caution**      *While removing the rail, ensure it does not scrape against the side of the Vacuum Chamber. Keep the rail level as you slide it clear of the Vacuum Chamber.*

---



---

**Caution**      *The Q0 RF-only quadrupoles are attached to the Mass Filter Rail on the front of the Vacuum Chamber Bulkhead. Care should be taken to ensure that the quadrupoles are not damaged.*

---

## Removing the Collision Cell




---

**WARNING**      **BIOHAZARDOUS MATERIAL** *Do not dispose of system components or subassemblies, including computer parts, in municipal waste. Dispose of replaced components and instruments according to established waste electrical equipment procedures.*

---

The Collision Cell is a standard quadrupole enclosed with two ceramic caps to provide a localized high pressure region for MS/MS collisional dissociation.

The ceramic caps that enclose the ends of the RF-only Q2 Quadrupole set contain the interquad lenses IQ2 and IQ3.

The Collision Cell is supported on eight support pins, and located by one locator pin, all of which are mounted on the Mass Filter Rail. It is held in position by two springs that stretch around the Collision Cell and hook to the Mass Filter Rail on either side. The springs also connect the voltages for the IQ2 and IQ3 interquad lenses.

1. Shut down the instrument.
2. Remove the Mass Filter Rail.

---

**Caution**      *Care should be taken to ensure the Mass Filter Rail and the ETP are kept clean and free of chemical or dust contamination. Cover Vacuum Chamber openings with foil if they are to be left open for any length of time. Always wear powder-free latex gloves when handling the Mass Filter Rail and Ion Optics to prevent contamination.*

---

3. Undo all connections to the quadrupoles, the top and bottom of the PCB, and disconnect all electrical wires to the unit.
4. Remove the PCB and the protective bar.

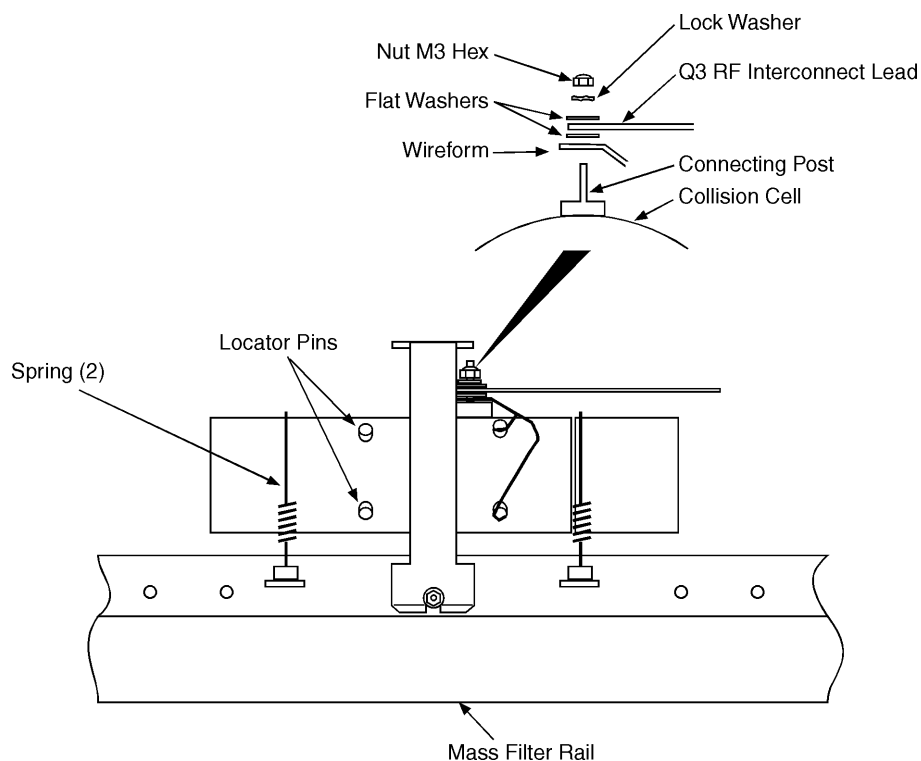


**Figure 4-11. Collision Cell Installation**

5. Undo the two screws at the bottom of the Mass Filter Rail and lift out the collision cell. See the figure above.

### Replacing the Collision Cell

1. Attach the two wireforms to the replacement Q2 rod set, as shown in the figure above. Make certain that Q2 is aligned so that the Q2 locator is positioned closest to the IQ2 Cup, and the wireforms oriented as drawn.

- 
2. Set the collision cell on the Mass Filter Rail. It rests on eight support pins and is located by one locator pin that fits inside the locator on the underside of the Q2 collar.
  3. Use a pair of needle nose pliers to stretch the two springs across the collision cell. Hook the spring catches into the cut outs on both sides of the rail.
  4. If not already connected, connect the black and orange wires to the springs; orange to the IQ2, black to the IQ3.
  5. Place an M3 SS flat washer over each of the connecting posts on the top of Q2 on top of the wireforms.
  6. Reconnect the Q3 RF interconnect leads to the connecting posts as shown in the previous figure.

### Replacing Q1 and Q3 Mass Filters

Q1 and Q3 are made from identical rod sets. What distinguishes the quadrupoles is the orientation of the rod set on the rail and the installation of the wireforms.

1. Remove the Mass Filter Rail.

---

|                |                                                                                                                                                                                                                                                                                                                                                       |
|----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Caution</b> | <b><i>Care should be taken to ensure the Mass Filter Rail and the ETP are kept clean and free of chemical or dust contamination. Cover Vacuum Chamber openings with foil if they are to be left open for any length of time. Always wear powder-free latex gloves when handling the Mass Filter Rail and Ion Optics to prevent contamination.</i></b> |
|----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

---

2. Remove the Collision Cell.
3. With a 2.5 mm Allen key, remove the four screws connecting the four Q1 RF interconnect leads to the interconnect PC board.
4. With a 2.5 mm Allen key, unscrew the two hex-head screws connecting the Q1 wireforms to the underside of the Q1 Interconnect PC board. See the Collision Cell figure.
5. Disconnect all wires from the underside of the Q1 interconnect PC board.
6. Remove the two screws connecting the Q1 interconnect PC board to the spacers mounted on the Mass Filter Rail, and remove the Q1 interconnect PC board.

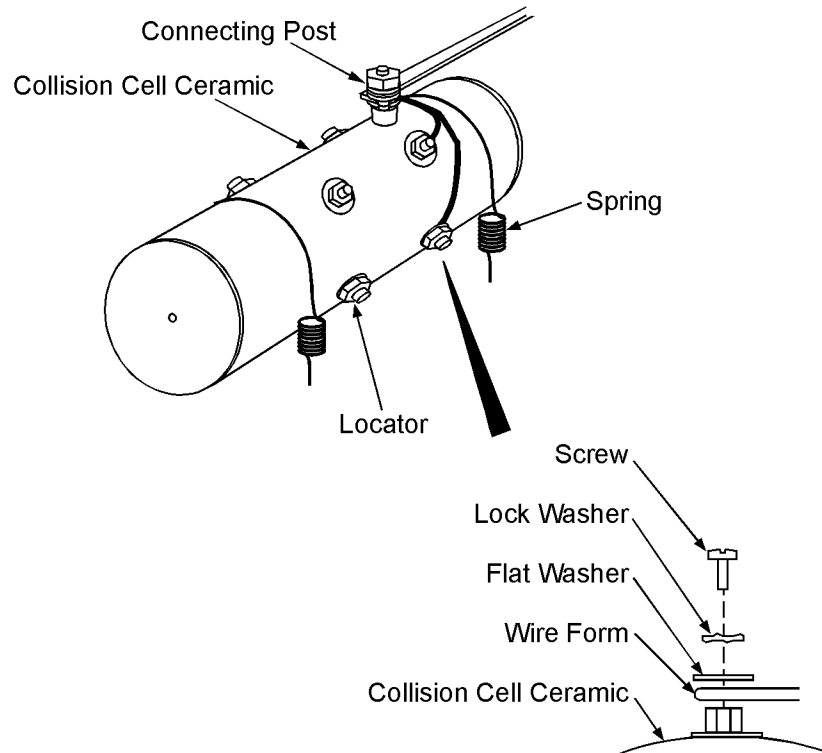


**Figure 4-12. Collision Cell**

7. Slide the interconnect PC board into the space vacated by the collision cell and remove it clear of the Mass Filter Rail.
8. Lift Q1 from the rail.
9. Unscrew the four screws that connect the two Q1 wireforms to the Q1 rod set. Remove and save the wireforms, the screws, washers and lock washers. See the Collision Cell figure.

### Replacing Q1 and the Interconnect PC Board



**WARNING** **BIOHAZARDOUS MATERIAL** *Do not dispose of system components or subassemblies, including computer parts, in municipal waste. Dispose of replaced components and instruments according to established waste electrical equipment procedures.*

1. Connect the two Quadrupole wireforms to the replacement Quadrupole as shown in the next figure.

---

**Note**                      *For Q1, the wireforms are attached to the rod set at the end opposite the locator on the bottom of the ceramic collar. Torque the screws to 60 inch ounces.*

---

2. Place the rod set into position on the Mass Filter Rail. The locator in the Q1 collar fits over the locating pin on the rail. The lip of the collar rests on four quad support pins.
3. Position the Q1 interconnect PC board on the Mass Filter Rail spacers and screw the interconnect PC Board to the spacers. Make certain the spring clip fixed to the interconnect PCB aligns with the indents on the ceramic collar.

---

**Note**                      *The interconnect PCB spring clip sits in the two indents on the quadrupole ceramic collar. The clip along with the two screws attaching the interconnect PCB to the spacers on the Mass Filter Rail hold the mass filter in position.*

---

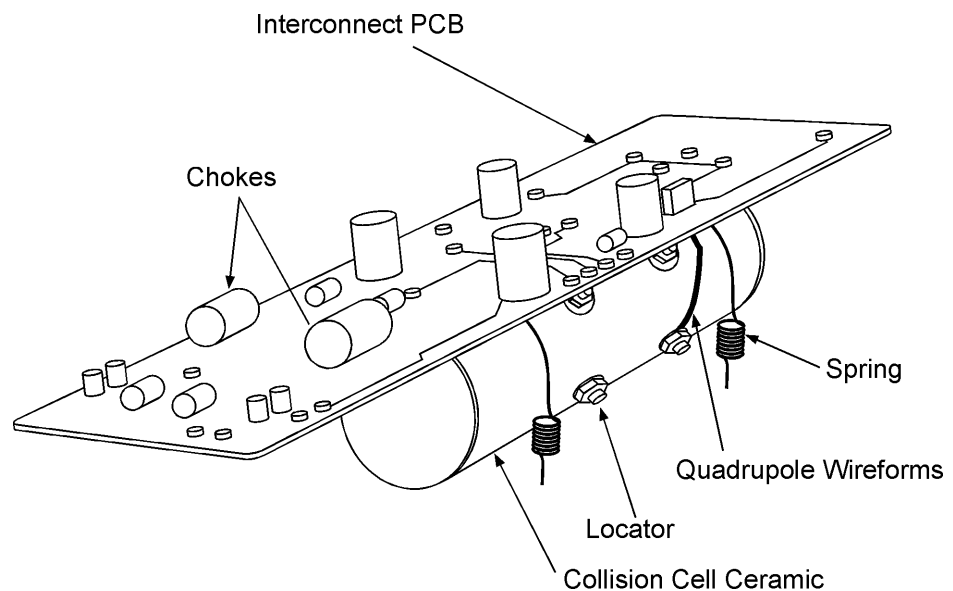


**Figure 4-13. Q1 Mass Filter and Interconnect PC Board**

4. Screw the quadrupole wireforms to the underside of the Interconnect PC board as shown in the Collision Cell figure.
5. Connect the RF interconnect leads to the Q1 interconnect PC board as shown in the figure above.

---

**Note**                      *It is essential that the leads are connected as shown so that the A and B rods of Q1, Stubbies and Q0 are electrically aligned.*

---

6. Connect all wires to the bottom of the Interconnect PC board.
7. Replace the collision cell.

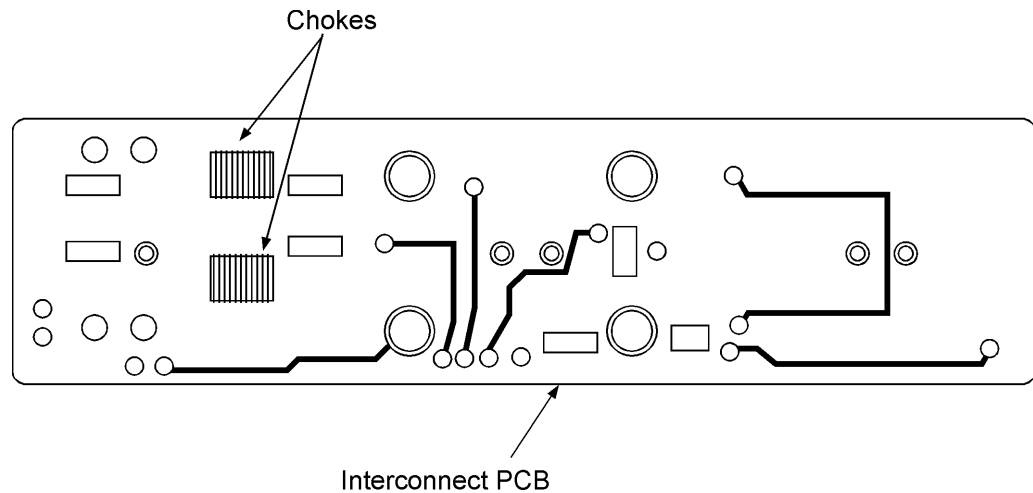


**Figure 4-14. Q1 - Q0 RF Connections**

8. Install the Mass Filter Rail.

### Removing Q3 and the Interconnect Board




---

**WARNING**                      **BIOHAZARDOUS MATERIAL** *Do not dispose of system components or subassemblies, including computer parts, in municipal waste. Dispose of replaced components and instruments according to established waste electrical equipment procedures.*

---

1. Remove the Mass Filter Rail.

---

**Caution**                      *Care should be taken to ensure the Mass Filter Rail and the ETP are kept clean and free of chemical or dust contamination. Cover Vacuum Chamber openings with foil if they are to be left open for any length of time. Always wear powder-free latex gloves when handling the Mass Filter Rail and Ion Optics to prevent contamination.*

---

2. Remove the Collision Cell.

3. With a 2.5 mm Allen key, remove the two screws connecting the Quadrupoles, all lens voltage wires, and the top and bottom of the PCB. See the figure above.
4. With a 2.5 mm Allen key, remove the two hex-head screws connecting the Q3 wireforms to the underside of the Q3 interconnect PC board.
5. Disconnect the white wire from the underside of the interconnect PC board. Remove all connections to the spring mounts for the PCB's U-shaped filter.
6. Remove the two screws connecting the Q3 interconnect PC board to the spacers on the Mass Filter Rail.
7. Remove the Interconnect PC board.
8. Lift the Q3 rod set from the rail.
9. Unscrew the four hex-head screws that connect the two wireforms to the Q3 Rods. Remove and save the wireforms, the screws, washers and lock washers.

### Replacing Q3 and the Interconnect Board

1. Connect the two Q3 wireforms to the replacement Q3 ceramic collar as shown in the previous figure.

---

|             |                                                                                              |
|-------------|----------------------------------------------------------------------------------------------|
| <i>Note</i> | <i>For the Q3 rod set the wireforms are connect to the rod set collar above the locator.</i> |
|-------------|----------------------------------------------------------------------------------------------|

---

2. Position the Q3 rod set on the Mass Filter Rail. The locator on the bottom of the Q3 collar fits over the locating pin on the rail. The lip of the Q3 collar rests on the four support pins.
3. Position the Q3 interconnect PC board onto the spacers on the Mass Filter Rail, and screw the interconnect PC Board to the spacers. Ensure that the spring clip fixed to the interconnect PC board aligns with the indents on the ceramic collar.

---

|             |                                                                                                                                                                                                                                              |
|-------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>Note</i> | <i>The interconnect PCB spring clip sits in the two indents on the quadrupole ceramic collar. The clip along with the two screws attaching the interconnect PCB to the spacers on the mass filter rail hold the mass filter in position.</i> |
|-------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

---

4. Screw the two Q3 wireforms to the interconnect PC board. (See the previous figure).
5. Connect the Q3 RF interconnect leads to the interconnect PC board as pictured in the Q1 Mass Filter and Interconnect PC Board figure.

---

**Note**                      *It is essential that the leads are connected as shown so that the A and B rods of Q2 and Q3 are electrically aligned.*

---

6. Connect the white wire to the connector on the bottom of the Interconnect PC board.
7. Replace the Collision Cell.
8. Install the Mass Filter Rail.

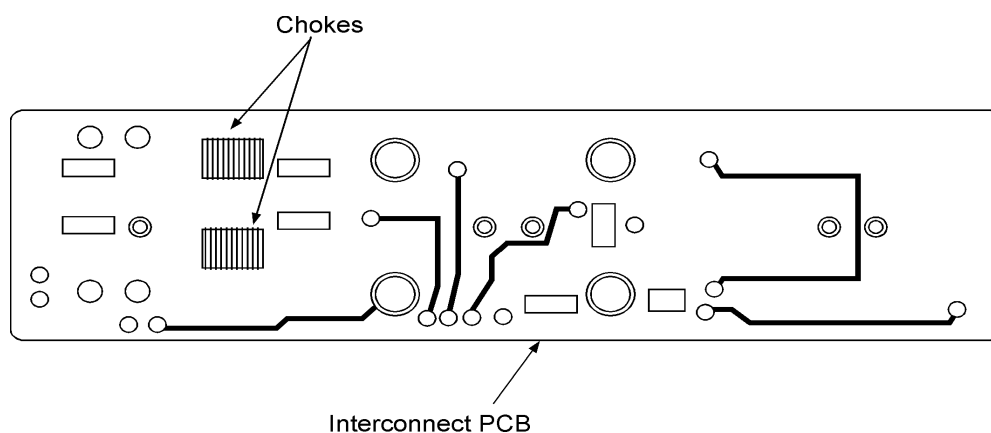


**Figure 4-15. Q3 - Q2 Connection Schematic**

### Installing the Mass Filter Rail

The Mass Filter Rail is installed upside down in the Vacuum Chamber with the quadrupoles actually hanging from the rail. This orientation aligns the Interconnect PC boards with the coil boxes so the vacuum feedthroughs connect with the Interconnect PC boards.

1. Before installing the Mass Filter Rail, wipe the inside of the Vacuum Chamber with a dust-free wipe. Perform the following tests to confirm the electrical connections:
  - Check that there is continuity between the connector pins and the individual ion optics elements according to the following table:

**Table 4-3. Continuity Check Pins**

| Pin | Ion Optic Element                 |
|-----|-----------------------------------|
| A   | Q3 Interconnect PC Board<br>Q2ROB |
| B   | IQ3                               |
| C   | IQ2                               |
| D   | Q2ROA                             |

---

|   |                                      |
|---|--------------------------------------|
| E |                                      |
| F | Stubbies<br>Q1 Interconnect PC Board |
| G | IQ1                                  |
| H | Q0 Rod Offset                        |

- Confirm that each pin on the connector has a path to the ground.
- Measure the resistance between the following points.  
(The resistances should measure  $20\text{ m}\Omega$  ).
  - Pin A to each connecting post on the collision cell
  - Pin F to each of the Stubbies rods
  - Red wire and each of the Q0 rods

---

*Note*                      *Q0, Stubbies and Q2 rod offset voltages (Q0 STRO, Q2RO) should be connected through a  $20\text{ m}\Omega$  resistor.*

---

- Confirm that the resistance of the two RF chokes is less than  $1\text{ k}\Omega$  .
  - Check that the Q0 shield is grounded.
  - Check that the exit lens is grounded.
  - Confirm visually that the Q1 and Q3 RF leads are connected to the Interconnect PC board.
2. Carefully insert the Q0 end of the Mass Filter Rail into the Vacuum Chamber from the detector end of the instrument.
  3. Slide the rail into the chamber, and turn the rail  $180^\circ$  so the rail is oriented with the ion optics facing down, hanging from the rail.
  4. Fit the rail so the four studs in the Vacuum Chamber housing fit through the corresponding holes in the Mass Filter Rail's rear flange. Place a flat washer over each of the studs and tighten the four M6 hex bolts.

---

*Note*                      *Always tighten the Mass Filter Rail's rear flange before sealing the front bulkhead. This ensures that the rail remains straight inside the Vacuum Chamber.*

---

5. Through the front end of the Vacuum Chamber, tighten the six lock nuts that connect the bulkhead flange to the Mass Filter Rail's front bulkhead.

---

|             |                                                                                                                                                                                                                        |
|-------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>Note</i> | <i>To ensure the Mass Filter Rail remains straight, snug the bolts in the order they are numbered in the Front Bulkhead figure. After they are snugged, tighten them to the specified torque in the same sequence.</i> |
|-------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

---

6. Connect the Curtain Gas Fitting and ion optics cable to the rear flange.
7. Close and latch the Vacuum Interface.
8. Clamp the Interface Pump line to the Interface vacuum flange.

### **Installing the Vacuum Feedthrough Connections**

9. Hold the first feedthrough by its ceramic collar, and insert it perpendicular to the Vacuum Chamber through the right rear punch out in the roof of the Q1 Coil Box.

---

|             |                                                                                                                                                                                                                      |
|-------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>Note</i> | <i>Firmly and smoothly, push the feedthrough into position in the Vacuum Chamber. Ensure that the feedthrough is inserted straight up and down so that it connects with the collar on the Interconnect PC board.</i> |
|-------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

---

10. While holding the feedthrough in place, slip the connecting sleeve over the end of the feedthrough.
11. Repeat steps 9 and 10 to install the second Q1 feedthrough directly in front of the first.
12. Push the locking mechanism tight against the feedthrough housing and tighten the thumb screw which holds the locking mechanism closed.
13. Repeat steps 9 through 12 to connect the Q3 feedthroughs.

---

|             |                                                                                                                                                                                                |
|-------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>Note</i> | <i>The procedure to install the Q3 feedthroughs is the same, with the minor difference that the feedthroughs are installed through the punch outs on the top left side of the Q3 Coil Box.</i> |
|-------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

---

14. Check the following before closing the coil boxes:
  - That the wireform sleeve connectors are seated securely over the two RF detector connectors at the back of the coil box.
  - That the wireform sleeve connectors are seated securely over both vacuum feedthrough connectors.
  - That the soldered connections joining the tuning capacitors to the wireforms is secure, and that the lead from the capacitors is not broken.

- 
- That the fly leads from the top and bottom of each coil are soldered securely to the wireforms. Each of the fly leads must not be closer to the walls of the coil box than the wireforms.
- 

---

|                |                                                                                       |
|----------------|---------------------------------------------------------------------------------------|
| <b>Caution</b> | <b><i>Failure to connect the coil boxes properly can damage the RF detectors.</i></b> |
|----------------|---------------------------------------------------------------------------------------|

---

15. Replace the Q1 and Q3 coil box covers and tighten the 16 hex-head screws with the associated washers.
16. Replace the ETP Module.
17. Connect the interface backing pump to the gas flange below the interface.
18. Connect the three interface voltage connections: Curtain Plate, Orifice and Focusing Ring.

### **Assembling the Ion Optics**

1. Mount the Mass Filter Rail in the base and clamp fixture. Slide the AC rods assembly in the Front Bulkhead, making sure that there is no clearance between the face of the AC rod collar and the face of the bulkhead.
2. Place the washers, spacers, and shield on the studs. Ensure that the tabs on the shield are perpendicular before installation.
3. Install the shield nuts. Tighten the top nut first, then the other two bottom ones. All nuts should be snug before the final tightening.
4. Check the AC rods assembly alignment by placing the Q1 mass filter on the rail and visually check the vertical alignment between the Stubbies and the mass filter. If the alignment is poor, replace the required components.
5. Attach the purple wire to the AC rods assembly using the washer and nut.
6. Fit the O-ring into the Front Bulkhead Flange and slide it over the mounting studs to the bulkhead. Loosely install the flat washers, lock washers and nuts. Tighten the nuts enough to hold the flanges together, but not enough to compress the ring.
7. Assemble the wireform to the AC rods assembly. Torque the screws to the required value.
8. Place the Q1 mass filter on the rail so that the locating pin engages the hole in the rear collar of the Mass Filter Rail. Verify that the ground surface of the collar is in contact with the four support pins by using a 0.05 mm feeler gauge.

- 
9. Install the retaining spring clamp screw, the three flat washers, and the lock washer into location on both sides of the Mass Filter Rail. Only insert the screw two to three turns.
  10. Install the clamps by pushing them down until the ends of the clamp latches on to the rail. Tighten the screws.
  11. Using the screw, flat washers, and lock washers, install the interconnect PCB. Mount the PCB. Install the center screws first, then install the remaining screws. Tighten the center screws first, then tighten the remaining screws.
  12. Using the screws and washers, connect the AC rod wireforms to the interconnect board.
  13. Using the screws, lock washers, and flat washers, connect Q1, Q2, and Q3 wireforms to the interconnect PCB.
  14. Install the protective bar and spring. Slide the spring over the end of the bar, and then slide the spring and bar over the pin on the rear flange. Line up the front of the protective bar with the pin on the Front Bulkhead and release.
  15. Connect the electrical harness wires to the bottom of the interconnect PCB.



# 5 Vacuum Control System

---

## 5.1 Overview

The Vacuum Control System is elemental to the safe and reliable operation of the instrument. A stable Vacuum Chamber pressure below  $1 \times 10^{-4}$  torr must be maintained to perform spectrographic analyses. This is accomplished using a Staged Pumping System.

The Vacuum System is controlled transparently by the System Controller. When the instrument is switched on, the System Controller automatically attempts to pump down the Vacuum Chamber. Only after reaching a stable operating pressure will the System Controller enable the instrument's analytical components.

The pressure inside the Vacuum Chamber is monitored using a hot cathode Vacuum Gauge. The System Controller continually monitors the Vacuum Gauge output and several physical interlocks to determine the vacuum status. If the vacuum integrity is breached, the System Controller will shut down the instrument's high voltages until the vacuum operating conditions are regained.

### 5.1.2 Pumping System

The Pumping System uses a staged combination of Turbomolecular (turbo) and Rotary Vane pumps to maintain the high vacuum pressure in the Vacuum Chamber. The Q0 region of the Vacuum Chamber is maintained at  $8 \times 10^{-3}$  torr by a TW 220 LPS Turbo Pump. The high vacuum Q1 region is maintained at about  $1 \times 10^{-5}$  torr by a TW 220 Turbo Pump. A D16E Rotary Vane Pump, referred to as the roughing pump, maintains the Differentially Pumped Interface at a pressure below 1.4 torr.

### 5.1.3 Turbo Pump

The TW 220 Turbo Pump is clamped horizontally to the side flanges at the back of the Vacuum Chamber. The Turbo Pump is not connected directly to the system electronics, but is controlled by a separate controller that is powered from the AC Distribution Board. The Turbo Pump and its controller are maintenance-free.

The TW 220 Turbo Pump has a cooling fan that is attached directly to the back of the pump. The 24 VDC cooling fan is connected to the System Controller through the motherboard, and runs continuously while the instrument is switched on.

### 5.1.4 Turbo Pump Controllers and Gas Control Assembly

The Turbo Pump Controllers, (as well as the Gas Flow Controller assembly for the gas control), are mounted on the chassis on the bracket at the inlet end of the Main Console as shown below.

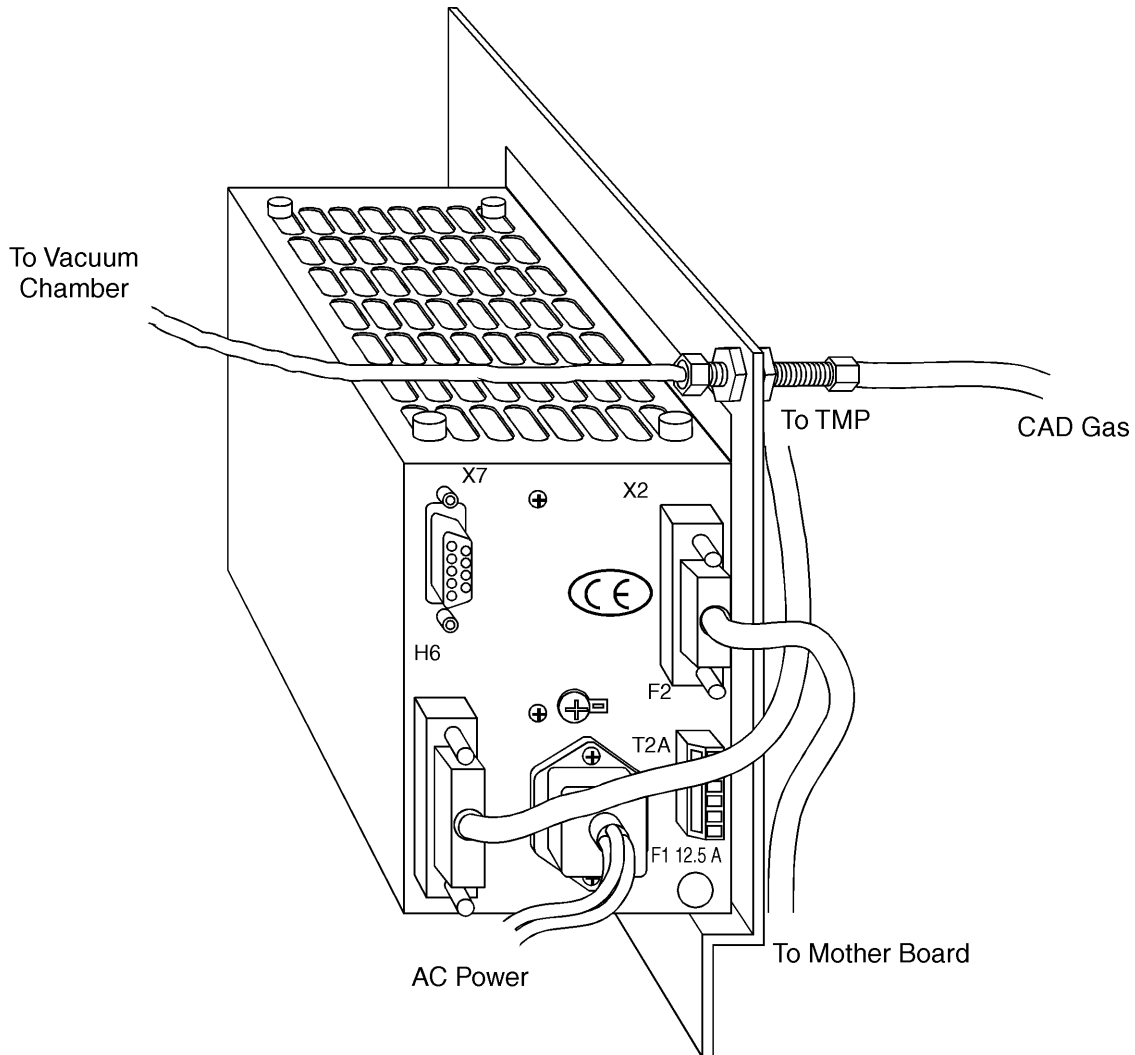


**Figure 5-1. Turbo Pump Controller and Gas Control Assembly**

The controller is a frequency converter that converts the single-phase AC power from the AC Distribution Board into the three-phase, variable frequency power required by the Turbo Pump's induction motors. The converter is controlled remotely by the System Controller as part of the Vacuum Control System.

---

The Turbo Pump Controller has four LEDs, labelled POWER, ACCELERATION, NORMAL and FAILURE, that indicate the pump's operational status.

Upon receiving a signal from the System Controller, the Turbo Pump Controller initiates a start-up procedure for the TW 220 Turbo Pump. This includes a self-diagnostic routine during which the controller outputs are turned off and the four indicator lights on the controller's front panel are illuminated. If the diagnostics routine completes successfully, the indicator lights, with the exception of the POWER indicator, are shut off. The Turbo Pump is then started and the ACCELERATION light illuminates as the turbomolecular fans accelerate. The pump is in normal operating mode when it reaches its rated rotational speeds. In normal operating mode, the POWER and NORMAL indicators are illuminated.

During normal operation, the controllers monitor the Turbo Pump for significant changes in turbo speed, operating parameter temperature, and load faults. Should a fault occur, the controller shuts off the respective pumps, and the controller's FAILURE indicators are illuminated.

The instrument's firmware detects the change in the Turbo Pump's status and attempts to re-establish operating vacuum conditions. If the Turbo Pump fails to stabilize after three attempts within a set time-out period, a hard fault is registered and the operator must restart the instrument. The next figure shows a flow diagram of the Vacuum Pump-Down Sequence.

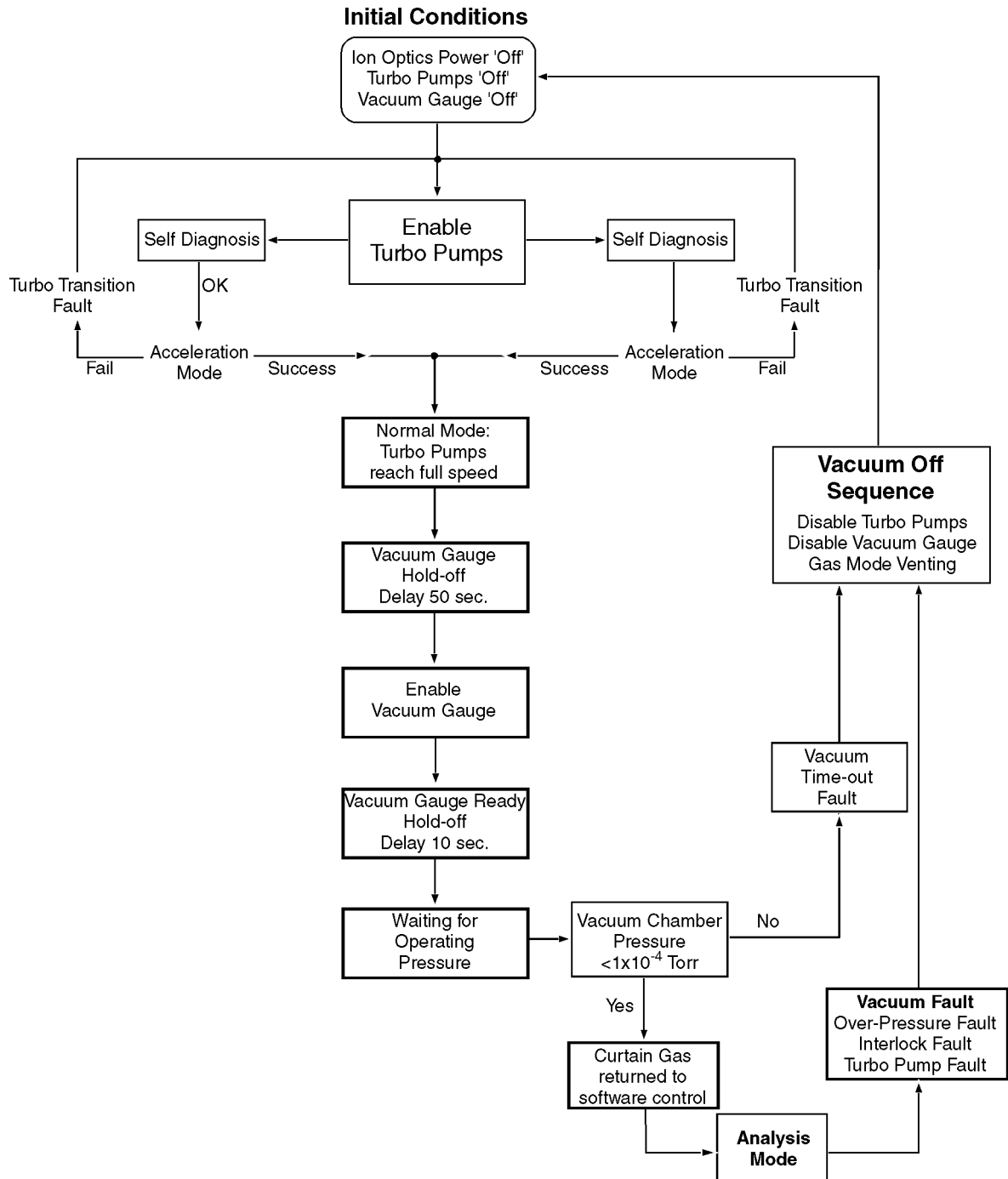


Figure 5-2. Vacuum Pump-Down Sequence

---

### 5.1.5 Rotary Vane Pump

The second stage of the Pumping System entails a Rotary Vane Pump. The Roughing Pump is connected to the exhaust ports of the Turbo Pump, and acts as a backing pump in support of the Turbo Pump.

The Roughing Pump is housed outside the instrument's main console and is not controlled by the system firmware or the Applications Computer. It also requires its own external 230 VAC, 50/60 HZ power supply, and is operated manually using switches mounted on the pumps.

The operational status of the pumps is monitored using pressure switch interlocks (see the Safety Interlocks section described later in this chapter). The pump must maintain a pressure low enough to satisfy the Interlocks before the System Controller will initiate the Turbo Pump. If the pressure in either pump's intake lines rises sufficiently to trip the Interlocks, the System Controller shuts down the Turbo Pump and the ion optic voltages.

The Rotary Vane Pump features an Anti-Suck Back Valve and a Gas Ballast Valve, which are described below. An optional smoke eliminator is strongly recommended if the pump is operated in a closed environment. The pump requires periodic maintenance that includes changing the pump fluid and, if the mist eliminator is installed, replacing the mist eliminator's coalescing element.



---

**WARNING**     *If biohazardous or hazardous material is injected into the instrument, all appropriate safety precautions should be taken when handling the pump's fluid and coalescing filter. The fluid will be contaminated and should be handled according to hazardous material safety regulations in the country of use. (For example, WHMIS, in Canada).*

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### 5.1.6 Roughing Pump

The Roughing Pump is a Leybold D16E Rotary Vane Pump (see the next figure). It eases the initial start-up load on the Turbo Pump by reducing the pressure in the Vacuum Chamber to about 0.300 torr. It also creates a pressure differential across each Turbo Pump's exhaust ports, ensuring that a back pressure does not overload the pumps.

The intake port of the Roughing Pump is linked to a vacuum line connecting the Turbo Pump exhaust ports via the Vacuum Pump Bulkhead.

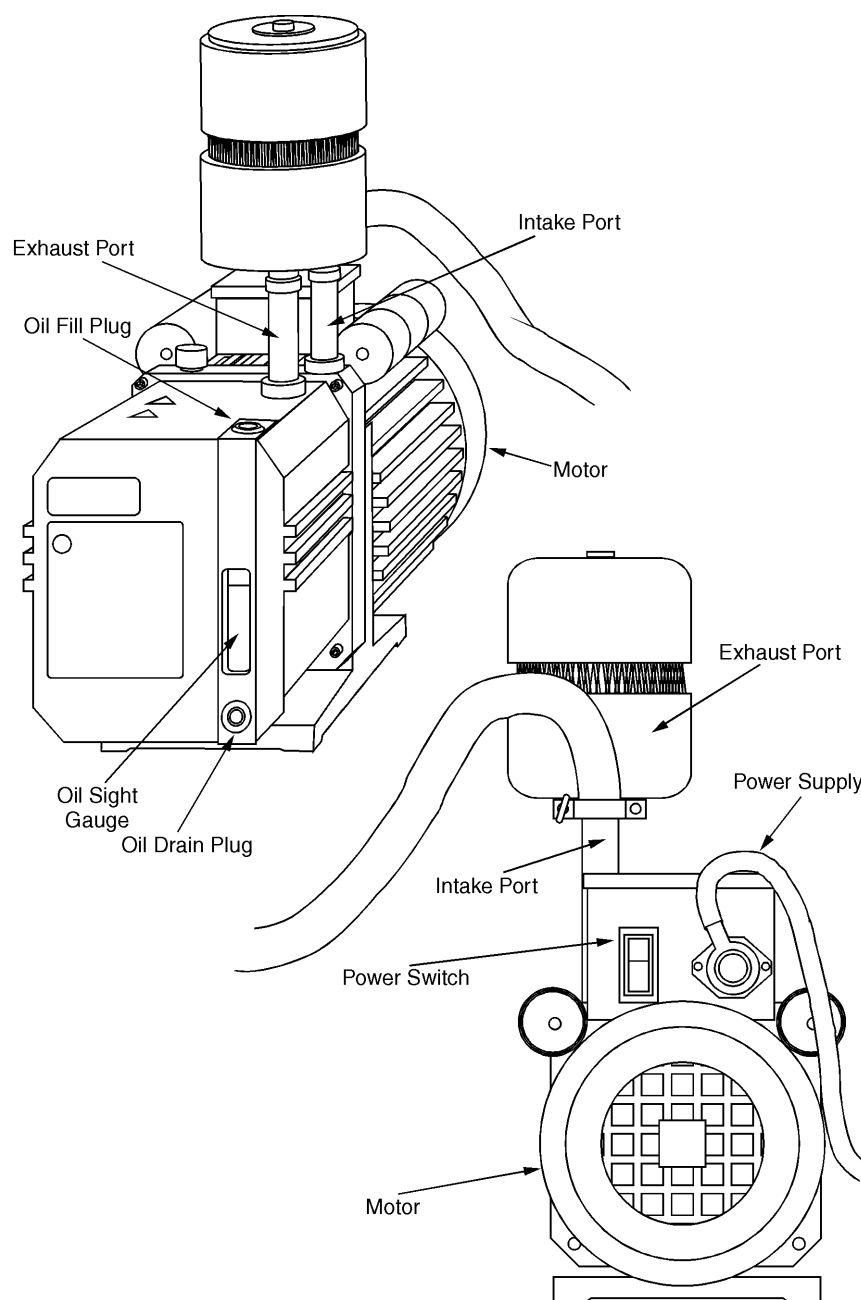


Figure 5-3. Roughing Pump

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### 5.1.7 Anti-Suck Back Valve

The Rotary Vane Pumps has a built-in Anti-Suck Back Valve that prevents any pump oil vapors to pump exhaust back into the Vacuum Chamber. The valve is triggered automatically when the pump is either shut off or there is a power failure. As the main shaft rotation slows, a valve opens. This causes the pumping chamber to vent and the Anti-Suck Back Valve to close. When closed, the valve seals the pump intake isolating the pump chamber from the instrument.

### 5.1.8 Gas Ballast Valve

The pump also comes with a manually controlled Gas Ballast Valve that can prevent water vapor and other condensable gases from condensing in the pump. Condensation degrades the pump's fluid, limiting the pump's performance and life expectancy.

When opened, the Gas Ballast Valve permits a controlled volume of air into the pump chamber. This lowers the partial pressure of condensable vapor in the pump and causes the pump temperature to rise. These two factors hinder condensation.

---

|             |                                                                                                                                                                                                |
|-------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>Note</i> | <i>Operating the roughing pump with the Gas Ballast Valve open, raises the pumps' ultimate pressure, increases the pumps' oil consumption, and increases the amount of oil in the exhaust.</i> |
|-------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

---

Given the controlled, dry atmosphere in the Vacuum Interface and the Vacuum Chamber, condensation is not a problem. Therefore, under normal instrument operating conditions, both Rotary Vane Pumps should be operated with the Gas Ballast Valve closed.

The Gas Ballast Valve on the roughing pump is controlled by the lever on the front of the oil casing (See the Roughing Pump figure). The Roughing Pump Gas Ballast Valve is controlled from the black knob on the top of the pump. To open the valve, turn the knob until one of the two holes on opposite sides of the knob aligns with the opening in the valve below.

### 5.1.9 Smoke Eliminator

If the instrument is operated in a closed environment, it is highly recommended that a Smoke Eliminator be installed on the exhaust ports on the Roughing Pump to prevent the emission of oil vapors into the environment, unless there is an oil exhaust system available.

### 5.1.10 Vacuum Gauge

A hot cathode Vacuum Gauge (see the figure below) is used to monitor the pressure inside the Vacuum Chamber. The gauge is connected directly to

a port on the rear of the Vacuum Chamber between the Turbo Pump (refer to the API 2000 System - Rear figure). It is controlled via the Vacuum Gauge Controller.

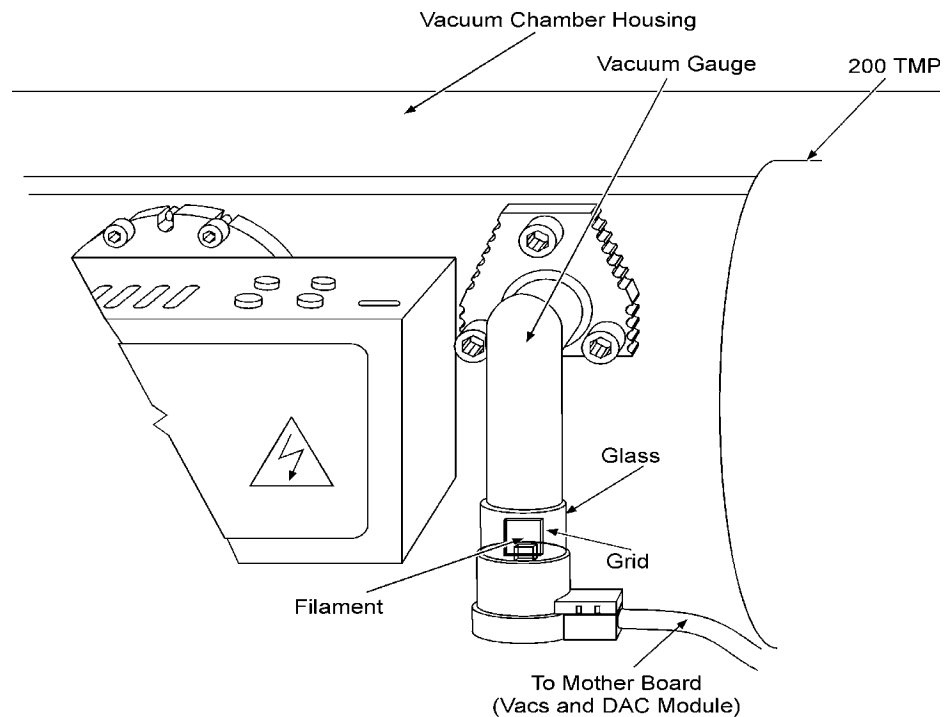


**Figure 5-4. Vacuum Gauge**

The Vacuum Gauge produces and measures an ion current that is proportional to the pressure inside the Vacuum Chamber. Electrons produced by a controlled current flowing through the filament inside the Vacuum Gauge accelerate towards the grid electrode that is held at a potential of +150V. The electrons collide with gas molecules inside the Vacuum Gauge tube creating positive ions. These ions are attracted to the collector electrode that is held at -13V.

The ion current measured at the collector is directly proportional to the vacuum pressure, the electron emission current flowing between the filament and the grid, and the gauge sensitivity factor. By regulating the electron emission current, the pressure inside the Vacuum Chamber can be directly determined from the ion current measured at the collector.

The power supply for the filament is +6.5 VDC from the DC Power Supply. The high voltage bias for the grid electrode (+150V) is generated by a power supply on the Ion Path DACs and the Vacuum Gauge Control Board inside the System Electronics Box. For description of the DC Power Supply

and the System Electronics Box, refer to the *Power and Electronics* section in this manual.

### 5.1.11 Vacuum Gauge Controller

The Vacuum Gauge Controller is located on the Ion Path DACs and the Vacuum Gauge Control Board inside the System Electronics Box. It performs the following functions (see the next figure):

1. Enables power to the Vacuum Gauge filament in response to the 'Gauge Enable' signal from the System Controller. This occurs after the Turbo Pump Controllers reach normal operating condition (usually below  $10^{-3}$  torr.
2. Regulates the voltage applied to the Vacuum Gauge filament to ensure a consistent electron emission current of 0.1 mA.
3. Provides the 'Vacuum Ready' signal to the System Controller to enable the ion path voltages once the pressure reaches  $10^{-4}$  torr.
4. Monitors the ion current signal at the Vacuum Gauge collector to ensure that the pressure inside the Vacuum Chamber remains below  $5.0 \times 10^{-5}$  torr.

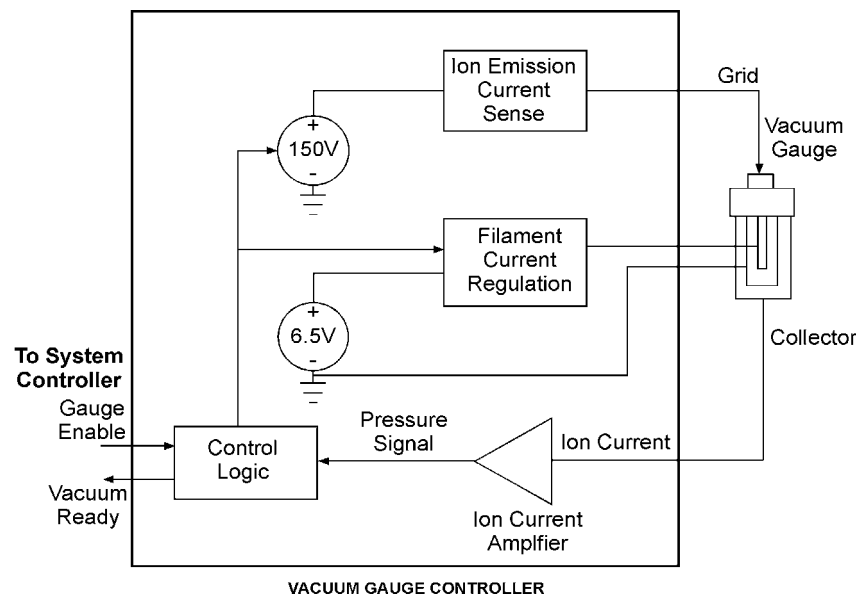


Figure 5-5. Vacuum Gauge Controller Block Diagram

If the pressure inside the Vacuum Chamber rises above  $10^{-4}$  torr, the Vacuum Gauge Controller sends a digital signal to the System Controller. The System Controller then initiates the 'Vacuum Off' sequence, disables

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power to the high voltage power supplies and the Turbo Pumps, and sets the ion path voltages to zero. The System Controller also instructs the Vacuum Gauge Controller to turn off the Vacuum Gauge to protect the filament. The System Controller attempts to recover the vacuum integrity automatically without operator intervention.

The low-level ion current signal measured at the collector is converted to a high-level voltage signal. The signal is scaled such that one volt is equivalent to  $1 \times 10^{-4}$  torr.

### **5.1.12 Gas Control System**

Three gas flows are required for the instrument. They are:

- Nebulizer Gas (Gas 1)
- Heater Gas (Gas 2)
- Curtain Gas

#### **Gas Flow Controllers**

The controller circuit works by sensing the pressure in the volume of gas between a variable inlet and a fixed orifice outlet. It continually adjusts the pressure by varying the inlet to match the sensed pressure with the set point pressure. If the pressure is too high, the inlet closes, allowing the pressure to drop. If the pressure is too low, the inlet opens to raise the pressure. As the measured pressure reaches the required set point, the analog valve starts to close to a point where it is opened enough to keep the flow through the controller the same as the flow through the orifice, therefore keeping the pressure constant at the outlet.

When a lower pressure set-point is required, the valve closes completely until the pressure at the outlet reaches the lower set-point (the pressure drops because the higher-pressured gas is flowing through the orifice without being replaced). At that time, the valve opens just enough to keep the pressure constant. Reaching a lower pressure set point from a higher one takes longer because lowering the pressure is achieved by letting the pressurized gas out through the small orifice while increasing is achieved by opening the inlet.

A temperature-compensated, pressure sensor is used to measure the pressure volume of gas between the valve and the orifice. This type of sensor gives an output that is linearly related to the gauge pressure and only needs to be amplified when used in the controller. No calibration trimports or temperature compensation networks are required. The gauge sensor output is amplified with an integrated circuit instrumentation amplifier.

The control actuator is a variable orifice valve (voltage sensitive orifice or VSO) that responds to current input. The current drives a solenoid that

---

opens the orifice against a spring (the VSO is closed with no applied current). The drive current is controlled through a power transistor.

The control loop has proportional integral differential (PID) compensation. The set-point inputs are differential analog voltage inputs with a 0 - 10 volt input controlling the pressure from 0 - 100 psig. Analog pressure monitor outputs are provided for system diagnostics. These outputs are buffered and sealed from the amplified pressure sensor output.

The readback of the Curtain Gas pressure monitor outputs allows the Curtain Gas pressure switches to be eliminated from the system. If the supply pressure drops below the set-point pressure, then the pressure drops and this is detected.

#### **Nebulizer Gas (Gas 1) Flow**

Nebulizer Gas is used to optimize the signal's stability and sensitivity. Typically, a value of 10 to 45 psi is used as applied by the Applications Computer.

#### **Heater Gas (Gas 2) Flow**

Heater Gas aids in the evaporation of the solvent that aids in increasing the ionization of the sample. The higher the liquid flow or the higher the aqueous composition of the solvent, the higher the Heater Gas temperature and gas flow required. However, a temperature that is too high, can cause premature vaporization of the solvent, and result in a high chemical background noise. A Heater Gas flow that is too high, can produce a noisy, or unstable signal. For more information, refer to the *API 2000 TurbolonSpray Ion Source Manual*.

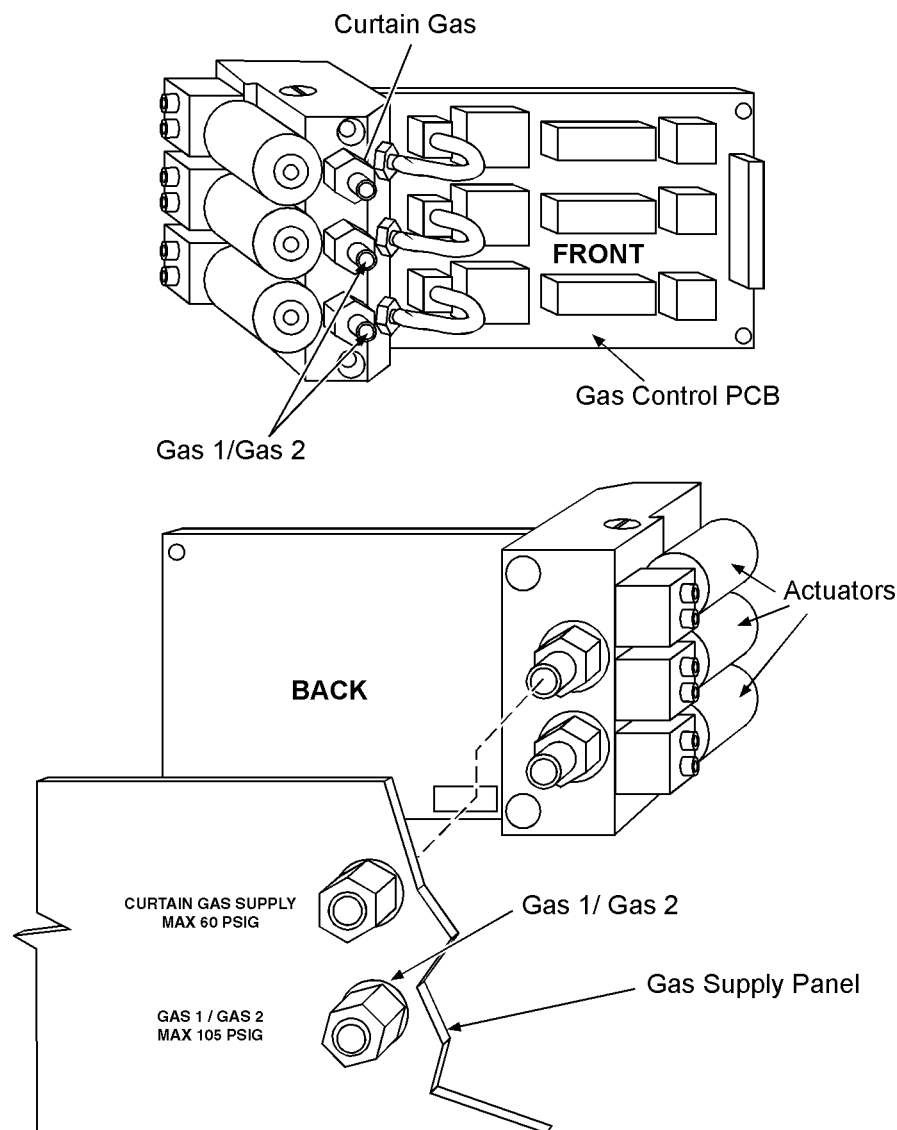


**Figure 5-6. Gas 1/Gas 2 Control Connection Schematic**

### **Curtain Gas Flow**

The Curtain Gas is used to isolate the Ion Source from the Vacuum Chamber. The gas acts, as its name suggests, like a curtain restricting the flow of air, sample and solvent into the Vacuum Chamber. For more information on the Curtain Gas, refer to the Vacuum Interface section in this manual.

The Curtain Gas is connected through the Gas Connection Panel on the chassis to the Gas Flow Controller assembly. For the Gas Flow Controller, the Curtain Gas is connected to the Gas Curtain Interface through the

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Vacuum Interface housing. The flow is interlocked to the Vacuum Control System and the ion optics by a pressure switch connected to the Gas Flow Controller's intake manifold. This is further described in the next section, Safety Interlocks.

### **Gas Control Sequence**

When the Vacuum Chamber pressure is stable below the Vacuum Ready setpoint of  $1 \times 10^{-4}$  torr, the three gas flows are controlled by the operator at the Applications Computer. However, when the instrument is either pumping-down or venting, the Curtain Gas flow rates are set by the System Controller independent of the software setting at the Applications Computer. By overriding the software Gas Flow Controller settings, the System Controller ensures the consistent, predictable behavior of the instrument during pumping-down or venting.

During the pumping-down or venting, the Curtain Gas is set to its maximum flow (that is, all three Gas Flow Controllers' valves are open), and the Curtain Gas is set to approximately half its maximum flow. In the Pump-Down sequence (described later in this chapter), the Vacuum Gauge Controller informs the System Controller that the vacuum is ready when the vacuum pressure surpasses the setpoint ( $1 \times 10^{-4}$  torr). Upon receiving the Vacuum Ready signal, the System Controller releases the gas control to the software.

After the Curtain Gas flow is returned to software control, the vacuum pressure typically drops rapidly from the Vacuum Ready setpoint at  $1 \times 10^{-4}$  torr to the operating pressure specification at  $1 \times 10^{-5}$  torr. This rapid decrease in vacuum pressure occurs because the Curtain Gas software setting is generally considerably lower than the maximum flow set by the System Controller.

### **5.1.13 Safety Interlocks**

The Vacuum Control System has safety interlocks to protect the instrument's sensitive electronic components. These interlocks prevent the normal operation of the instrument in the event that certain operating parameters outside the direct control of the system circuitry are not maintained.

The two interlocks that directly affect the pumping sequence are:

- Curtain Gas Flow
- Roughing Pump Pressure

When an interlock is triggered, the Vacuum Off Sequence is initiated (see the Vacuum Control Sequence section in this chapter). The Turbo Pumps are disabled and the ion optic voltages are set to zero. When the interlocks

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are recovered, the system will automatically attempt the Pump-Down Sequence.

A set of interlocks prevents the instrument from switching to 'Analysis Mode' if a valid Ion Source is not properly installed. These interlocks do not, however, affect the Pumping System. For more information, refer to the Pumping System section at the beginning of this chapter.

### **Curtain Gas Interlocks**

Curtain Gas flow is essential to the consistent and safe operation of the instrument. Without a significant flow of Curtain Gas, the Vacuum Chamber draws ambient air from the Ion Source, the moisture and composition of which can negatively affect the operation of the instrument. Even though small amounts of Curtain Gas enter the Vacuum Chamber with the sample, the operation of the instrument is not detrimentally affected because the quantity and the composition is controlled. For more information, refer to the Vacuum Interface section in this manual.

A pressure switch connected to the Curtain Gas flow between the gas cylinder and the Gas Flow Controller is triggered if the pressure drops below a setpoint that corresponds to a flow rate of 0.7 L/min. If the interlock is tripped, the Vacuum Off Sequence is initiated (see the Vacuum Control Sequence section below) and the Turbo Pumps and the ion optic voltages are disabled. The instrument automatically attempts to pump down when the Curtain Gas Flow interlock is satisfied.

### **Roughing Pump Interlock**

A pressure switch attached to the vacuum line that connects the exhaust port of the Turbo Pumps to the Rotary Vane Roughing Pump acts as the indicator of the Roughing Pump's operational status. If the pressure in the vacuum line rises significantly and triggers the interlock switch, the Vacuum Off Sequence is initiated. The Turbo Pump shuts down and the ion optics are disabled.

The instrument automatically attempts to pump-down when the vacuum pressure in the Roughing Pump line is regained and the pressure switch interlock closes.

## **5.1.14 Vacuum Control Sequence**

On power-up, the instrument goes directly into Pump-Down Mode (see the Operating Modes figure). The Pump-Down Sequence is controlled by the firmware independent of the Applications Computer. This means that the Pump-Down Sequence, once initiated, is transparent to the user.

When a stable operating vacuum pressure is established and the required safety interlocks are satisfied, the instrument switches directly to 'Analysis Mode'. In 'Analysis Mode', the instrument is ready for spectrographic

analysis; the ion path voltages, gas flows, and the other operating parameters are controlled by the operator at the Applications Computer.

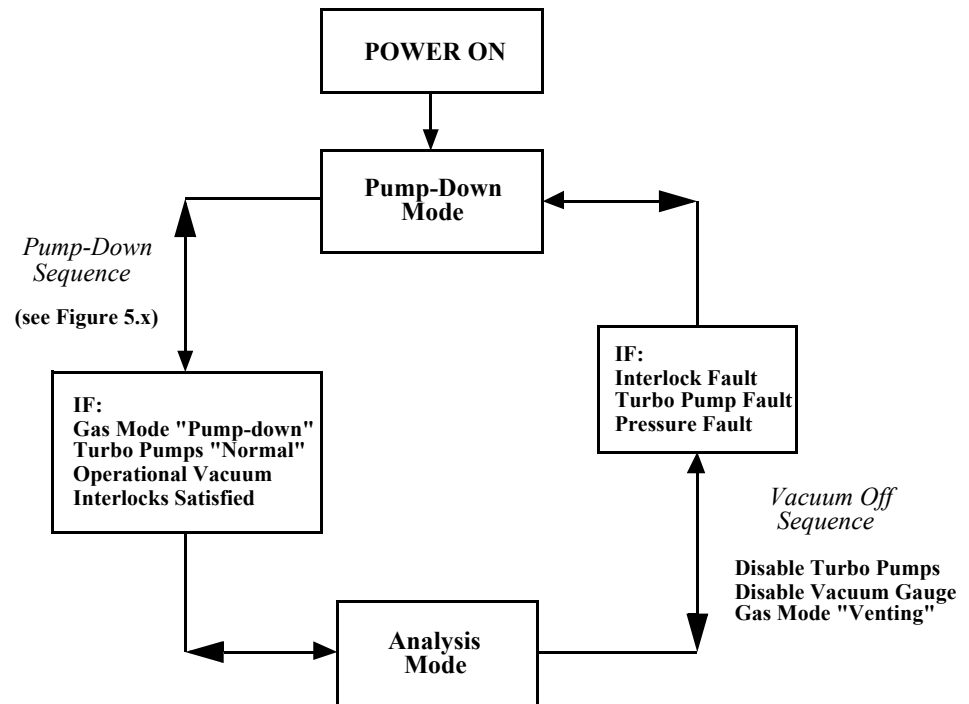


Figure 5-7. Operating Modes

### Pump-Down Sequence

The Pump-Down Sequence is initiated when the instrument's power is switched on. Before attempting to initiate the Turbo Pump, the status of the system interlocks and fault conditions, including the Vacuum Gauge and Turbo Pump status, are evaluated. The proper setting of the Curtain Gas is verified, and when the initial conditions are correct, the control sequence initiates the Turbo Pump.

The status of the Turbo Pump is monitored by the firmware control circuitry (see the Turbo Pump and Turbo Pump Controller sections described earlier in this chapter). If the Turbo Pump does not reach the normal operating mode within a specified time-out period, the sequence triggers a 'turbo transition fault'. The system attempts to start the pumps three times. If the pump fails to stabilize after the three attempts, the firmware controller registers a hard fault and aborts the Pump-Down Sequence.

The Turbo Pump switches to the normal operating mode when its turboblades reach its rated rotational speeds. Power to the Vacuum Gauge filament is enabled 55 seconds after the Turbo Pump has reached its normal status. The Vacuum Gauge output is not monitored until 10 seconds

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after the gauge has been enabled. This delay allows the gauge output to stabilize before it is used as a variable in the Pump-Down Sequence.

There is a two-stage pump-down sequence. When the Vacuum Chamber pressure reaches  $10^{-4}$  torr, the gases are put under the control of the Analyst software. Before the electrons are enabled, the vacuum must reach  $2 \times 10^{-5}$  torr.

### **Vacuum Off Sequence**

When the Vacuum Off Sequence is initiated, the Turbo Pump, ion optics and Vacuum Gauge are disabled, and the gas flows are set to the values in the Pump-Down state. The sequence then recycles to the beginning of the Pump-Down Sequence. If the sequence fails in three attempts to regain a stable operating pressure, a hard fault results and the system exits the Pump-Down Sequence.

---

## 5.2 Gas Control Service Procedures

The orifices for the three Gas Flow Controllers have a maximum pressure rating of 100 psig, well within the recommended setting for the Curtain and Nebulizer gas source pressure of 100 psig. The orifices fit firmly into the intake manifold and cannot be replaced individually in the field. Should one of the orifices prove to be defective, the entire intake manifold assembly must be replaced.

### Removing the Gas Flow Controller




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**WARNING**      **BIOHAZARDOUS MATERIAL** *Do not dispose of system components or subassemblies, including computer parts, in municipal waste. Dispose of replaced components and instruments according to established waste electrical equipment procedures.*

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*Note*                      *You can use the following procedure to all three Gas Flow Controllers.*

---

1. Shut down the instrument.
2. Remove all covers.
3. Disconnect the three gas connections from the control block.
4. Disconnect the input gas leads.
5. Remove the entire Gas Flow Controller.

### Replacing the Gas Flow Controller

1. Position the Gas Flow Controller against the bracket and thread the two hex-head screws with flat washers through the outlet manifold to the bracket.
2. Connect the Curtain Gas supply cable, Gas 1 and Gas 2 cable connectors to the solenoid valves.
3. Connect the gas lines to the fittings as shown in the Gas 1 / Gas 2 Control Connection Schematic and TW 220 Turbo Pump Mount figures respectively.

---

### Assembling the Gas Controller Module

1. Clean the block and fittings as per standard cleaning procedures.
2. Press the flow orifice into the Swagelok fitting. Using the stamping fixture to hold the fitting, stamp the side of the fitting: F36.
3. Install the 1/8" Swagelok fitting into the control block.
4. Install the two 1/4" Swagelok fittings into the bottom of the control block.
5. Install the two 10-32 plugs into the end of the control block.
6. Install the three tube barbs into the face of the control block.
7. Place the control block on a flat surface so that the valve-mounting surface is facing up. Install the six O-rings in the counterbores.
8. Using the screws and washers, mount the first valve on the control block, making sure that the valve ports are facing the control block.
9. Mount the remaining two valves on the control block.
10. Remove the protective plastic covering the Turbo Pump inlet ports. Using isopropanol and a clean wiper, remove any glue residue.
11. Remove the two Turbo Pump centering rings from their packages and discard the outer metal ring from both. Insert the centering rings into the Turbo Pump ports on the Vacuum Chamber.
12. Mount the Turbo Pump to the rear of the Vacuum Chamber by sliding the mounting plate on the two dowels in the rear of the Vacuum Chamber, making sure that the pump fits snugly on the dowel pins.
13. Using mounting bolts, lock washers, and flat washers, fasten the Turbo Pump to the Vacuum Chamber.
14. Install the vacuum gauge to the rear of the Vacuum Chamber using the KF16 centering ring, the quick connect clamp, and the mounting screws. Ensure that the gauge is pointed straight down.

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|             |                                                                                     |
|-------------|-------------------------------------------------------------------------------------|
| <i>Note</i> | <i>The mounting screws should be tightened evenly by hand. DO NOT use a wrench.</i> |
|-------------|-------------------------------------------------------------------------------------|

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## 5.3 Turbo Pump Maintenance

The Splitter Assembly unit is part of the Turbo Pump, and is an FRU that can be replaced in the field. To replace the Turbo Pump, you must replace the entire Splitter Assembly unit.

### Replacing the TW 220 Turbo Pump

The TW 220 is part of the Splitter Assembly.

1. Shut down the instrument.

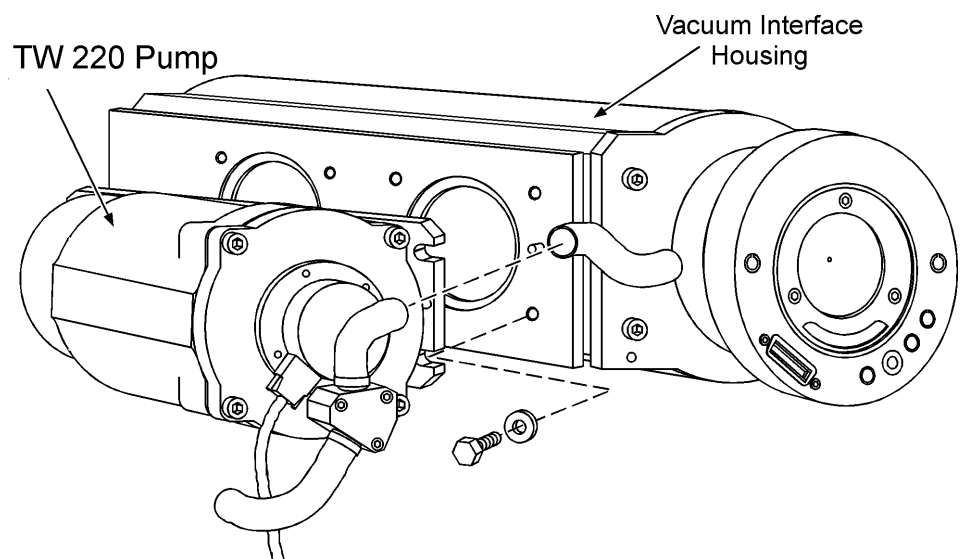


**Figure 5-8. TW 220 Turbo Pump Mount**

2. Open the Source Cover.
3. Remove the vacuum hose from the Interface.
4. Remove the Front Cover.
5. Unscrew the three screws and remove the T-connection from the TW 220 Turbo Pump.
6. Unscrew the two screws that connect the controller connection to the Turbo Pump.
7. Unscrew the four bolts that attach the Splitter Assembly to the Vacuum Chamber. Using a wrench, remove the Splitter Assembly unit.
8. Ensure that the two centering rings are in place and slide the Splitter Assembly unit back into position.

- 
9. Slide the Turbo Pump into the Splitter Assembly.
  10. Tighten the four bolts diagonally to center the unit.
  11. Using the two screws, replace the controller connection.
  12. Attach the T-connection to the TW 220 Turbo Pump by using the three screws you removed in step 5.
  13. Reattach the vacuum hose to the Vacuum Interface.

### Replacing the D1220 Turbo Pump Controller



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**WARNING**     **BIOHAZARDOUS MATERIAL** *Do not dispose of system components or subassemblies, including computer parts, in municipal waste. Dispose of replaced components and instruments according to established waste electrical equipment procedures.*

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The Turbo Pump Controller is secured by a bracket that is hinged to the chassis. The hinge allows the controller to be removed with minimal disassembly.

1. Shut down the instrument.
2. Remove all covers.
3. From the back of the controller, remove the electrical connections, the ground strap and disconnect the AC power cable and the TW 220 cable connecting the controller to the turbo pump. Also disconnect the ground bracket from the back of the controller.
4. Using an 8 mm nut driver, remove the four nuts that secure the controller box to the back plate.
5. Disconnect the remote control wires from the back of the controller. The wires are part of the Turbo and Gas Flow Controller harness.
6. From the front of the instrument, remove the two Philips head screws that attach the controller to the bracket.
7. Remove the two hex-head screws that secure the front of the bracket to the chassis.
8. The bracket is hinged at the back. With the front bolts removed, you can lift the chassis and remove the controller from the front.
9. Raise the controller bracket and slide the controller over the lowered front panel clear of the controller bracket.

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**Note**      *You may need two hands to remove the controller. If this happens, raise the bracket high enough so that the controller can be easily removed. Place shims under the bracket support legs.*

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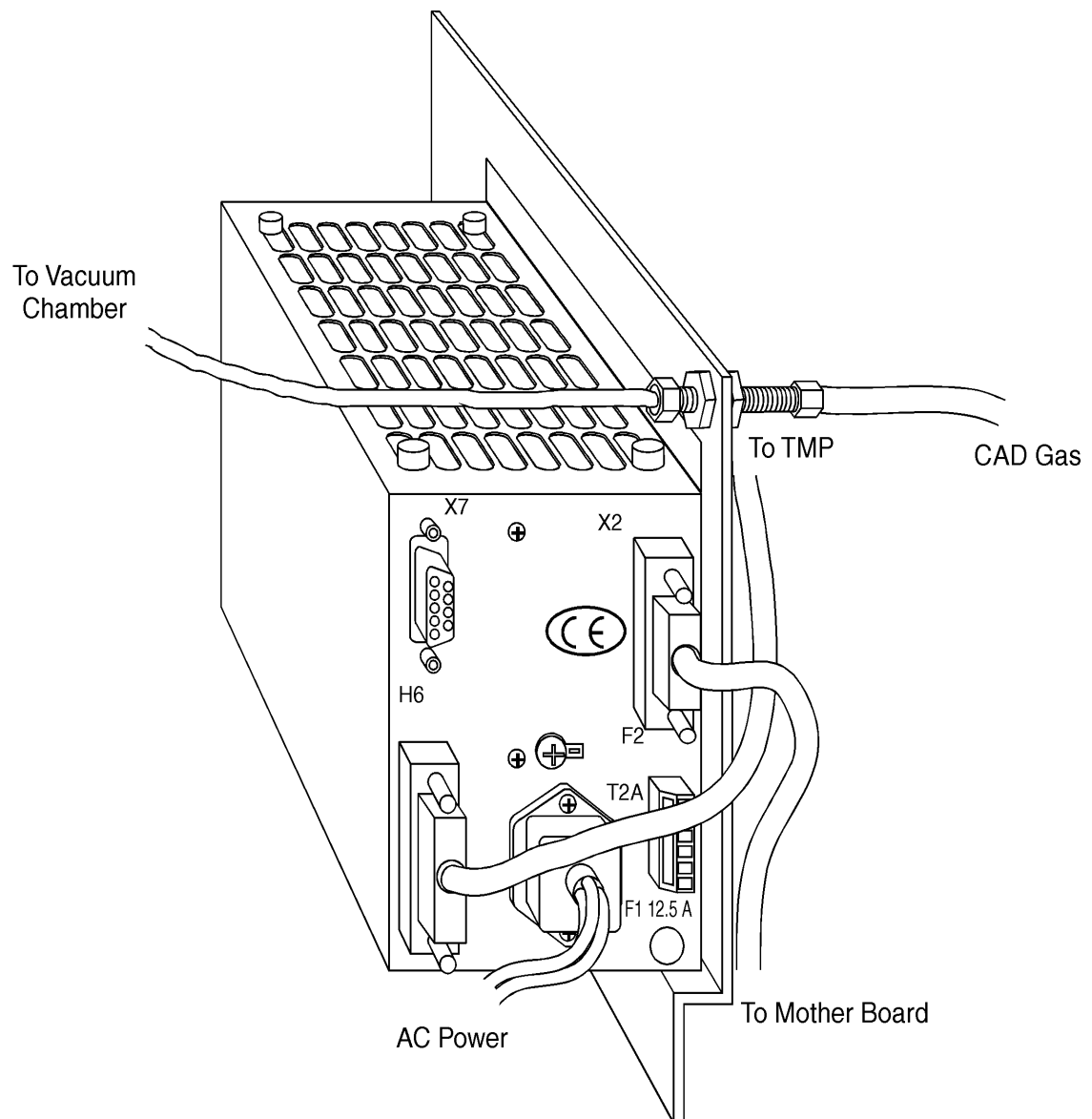


**Figure 5-9. Turbo Pump Controller Connections**

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### **Replacing the D1220 Controller**

10. Check that the voltage setting is set at the 220V setting as shown in the figure above. If the indicator does not appear in the 220V window, open the box, remove the circuit board and reinsert it so the 220V value is readable.
11. Reverse the steps from 3 to 10 to replace the D1220 Controller.

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## 5.4 Rotary Vane Pump Maintenance

The routine maintenance for the rotary vane pump involves maintaining the level and quality of the pump oil. If the pump oil level drops, or the oil becomes contaminated, the pump performance will deteriorate and the pump will suffer increased wear and may ultimately seize.

The pump oil level for both pumps should be maintained between the marks on the oil sight glass when the pump is operating at close to its ultimate pressure. If the pump oil falls outside these boundaries oil should be added or drained.

The pump manufacturer recommends that the pump oil be changed under the following conditions:

- When the oil is contaminated or every six months
- Before and after the pump is stored for a lengthy period

The condition of the pump oil can be determined by observing when the pumps are operating. When in good operating condition, the oil will appear light in color and be relatively clear. If the pump oil becomes dark, appears dirty, or excessively turbid, the oil should be changed.

The D16E Roughing Pump has a separate sight gauge on the side of the oil casing for observing the pump oil condition (see Roughing Pump figure).

### Replacing the Rotary Vane Pump Oil

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|             |                                                                                                                                                                            |
|-------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>Note</i> | <i>The pump oil should be changed when the pumps are warm. Use the replacement oil as specified on the pump identification tag. Use HE 200 for the D16E Roughing Pump.</i> |
|-------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

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|                |                                                                                                                                                                                                                                                                                                                                                                                               |
|----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>WARNING</b> | <b><i>If biohazardous or hazardous materials are injected into the instrument, all appropriate precautions should be taken when handling the pump fluid and the mist filter. Deposit biohazardous material in appropriately labelled containers. Potential risk of severe personal injury if proper procedures for handling and disposing of biohazardous materials are not followed.</i></b> |
|----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

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1. Shut off and vent the instrument.
2. While the Rotary Vane Pump is still warm, remove the drain plug with an 8 mm Allen key and drain the pump oil into a suitable container.
3. When the flow slows, replace the drain plug and switch the pump on for not more than 10 seconds.

- 
4. Remove the drain plug once more and allow the remaining oil to drain.
  5. Replace the drain plug. Be certain the flat gasket is in good condition and properly in place.
  6. Open the oil-fill plug with an 8 mm Allen key wrench and fill the pump with 1 quart (app. 950 ml) of the specified pump oil.
  7. Replace the oil-fill plug.

### **Cleaning the Filter Trap**

The Roughing D16E Rotary Vane Pump has a filter trap inside its intake tubes. If the traps become clogged, the pump performance will deteriorate.

Given the controlled atmosphere in the Vacuum Interface and Vacuum Chamber, it is unlikely that the filter trap will become clogged under normal operating conditions. However, if the pump performance deteriorates, the trap should be examined and cleaned, if necessary.

1. Shut down and vent the instrument.
2. Remove the vacuum intake line from the pump.
3. Lift the filter trap from inside the intake.
4. If necessary, remove any material in the trap.
5. Replace the trap and reconnect the pump.

### **Replacing the Mist Eliminator Filter**

If the pump has the optional mist eliminator installed on the pump exhaust, the mist eliminator filter should be replaced periodically.



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**WARNING**     *If biohazardous or hazardous materials are injected into the instrument, all appropriate precautions should be taken when handling the pump fluid and the mist filter. Deposit biohazardous material in appropriately labelled containers. Potential risk of severe personal injury if proper procedures for handling and disposing of biohazardous materials are not followed..*

---

1. Shut off and vent the instrument.
2. Unscrew the thumb screw on top of the mist eliminator and lift away the top section of the eliminator to expose the coalescing filter.
3. Lift the filter out of the top of the Mist Eliminator housing.
4. Drop in a new filter.
5. Close the Eliminator and replace the thumb screw.

## 5.5 Vacuum Gauge Service Procedures

The vacuum gauge must be replaced when the filament voltage required to maintain the 0.1mA electron emission current surpasses 3.5V. Normally the filament requires 1.5V to 3.5V to maintain the required electron emission current.

The filament voltage can be read from test point TP1 on the Ion Path DACs and Vacuum Gauge Controller Board. Normally the green LED D21 on the Ion Path DACs and Vacuum Gauge Controller illuminates when the vacuum gauge is enabled. However, if the filament voltage reaches the 3.5V ceiling, the LED will not illuminate when the gauge is enabled.

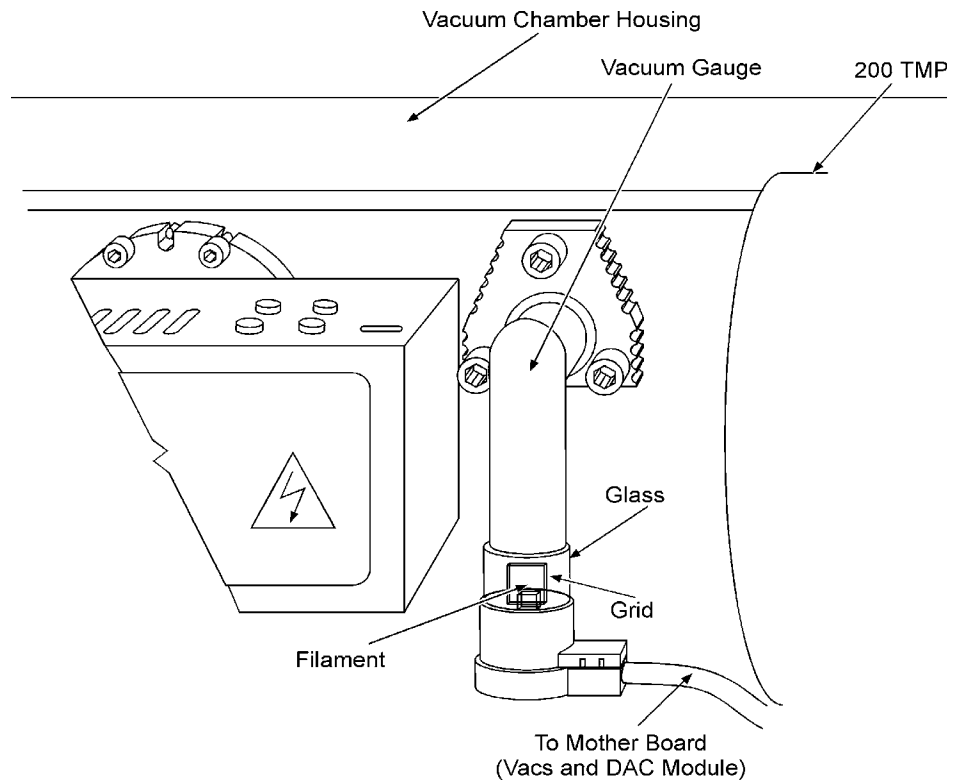


**Figure 5-10. Vacuum Gauge Assembly**

### Removing and Replacing the Ion Vacuum Gauge



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**WARNING**     **BIOHAZARDOUS MATERIAL** *Do not dispose of system components or subassemblies, including computer parts, in municipal waste. Dispose of replaced components and instruments according to established waste electrical equipment procedures.*

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1. Shut down and vent the instrument.
2. Open the Top Cover.
3. Disconnect the connector from the vacuum gauge.
4. Remove the Vacuum Gauge assembly by unscrewing the clamp that connects the gauge to the Vacuum Chamber.

To replacing the Ion Vacuum Gauge:

5. With a clean lint-free wipe, clean the vacuum fitting on the new gauge and the sealing surface of the Vacuum Chamber.
6. Re-clamp the Vacuum Gauge assembly to the Vacuum Chamber.
7. Reconnect the connector to the gauge.

# 6 Power and Electronics

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## 6.1 Introduction

The most important part of the API 2000 is the System Controller and on-board computer that controls and co-ordinates the operation of the instrument. The System Controller controls all aspects of the API 2000, including the ion optics and mass filter settings, scanning parameters, data accumulations and preliminary data processing, without relying on the Applications Computer.

Data acquisition experiments are designed by the operator at the Applications Computer and uploaded to the System Controller. The System Controller then initiates the acquisition and relays the data back to the Applications Computer in the form requested. At the Applications Computer, the data can be analyzed using the specific data processing software: MassQuan, Multiview, or BioToolBox.

The computer power embedded in the System Controller frees the Applications Computer to perform other independent tasks, including post-data acquisition analysis or other user-specific applications.

This chapter outlines the instrument's power requirements and the power distribution module that distributes the power in the necessary form to the system's electronics and the main module equipment. It then describes the System Controller and the other modules in the System Electronics Box that control the instrument's spectrographic functions.

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## 6.2 Power Distribution Module

The Power Distribution Module is the interface between the external 230 VAC power supply and the instrument's electronics. The module supplies all required power for operating the mass spectrometer.

Operating the instrument requires two separate 230 VAC power sources at 50 or 60 Hz. One single phase 230 VAC power source is required for the instrument's Main Console. The second is required for the two externally mounted Rotary Vane Pumps. The Applications Computer, printer and other accessories (including LC equipment) are powered separately from standard wall outlets. An optional Line Adjustment Transformer can be purchased to provide accurate, consistent power for the instrument and the two Rotary Vane Pumps.

The instrument operates within design specification with line voltage variations of 230 VAC  $\pm 5\%$  VAC. The OEM equipment including the Rotary Van Pumps specify that line variations also be minimized to 230 VAC  $\pm 5\%$  VAC.

All operating voltages for the instrument are generated from the 230 VAC. The power is sub-divided at the AC Distribution Board and distributed by detachable cables to the Main Console equipment. A DC Power Supply converts the AC power into three distinct DC voltages.

### 6.2.1 AC Power Distribution

The AC Distribution Board is the instrument's main power distribution center. The 230 VAC power enters the Main Console by a detachable cable and is fed through a filter to the main power switch on the Power Distribution Panel. The switch doubles as a circuit breaker that trips and disables power to the instrument, if there is a power surge. When the Power switch is "ON", power is directed straight to the AC Distribution Board where it is divided and connected by detachable cables to the following equipment on the Main Console (see the next figure):

- Main DC Power Supply
- Card Cage Cooling Blower
- Heated Nebulizer Inlet (optional)

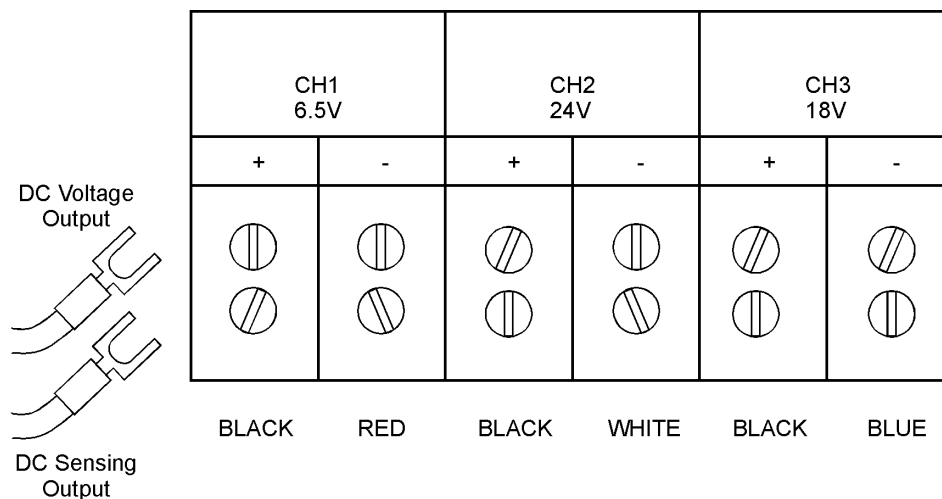


**Figure 6-1. DC Power Supply Connections**

### 6.2.2 DC Power Distribution

The DC Power Supply converts the 230 VAC input power from the AC Distribution Board into four DC voltages: +5.0V, -18V, +24V A and +24V B. The DC voltages are supplied to the motherboard where they are available to the modules that include the System Electronics Box and the main module equipment. The DC Power Supply has a feedback sensing circuit that ensures the consistency of the DC voltages across the motherboard.

---

## 6.3 System Electronics Box

The System Electronics Box houses the following seven printed circuit boards:

- System Controller
- Ion Path DACs and Vacuum Gauge Controller
- Lens Power Supply
- HV Power Supply
- QPS Exciter
- Q1 Amplifier
- Q3 Amplifier

These boards are contained in individual modules (see System Electronics Box - Layout figure) to reduce potential electro-magnetic radiation and susceptibility problems. Each module plugs into the common Motherboard which forms the back of the System Electronics Box. Together, the modules control the instrument and convert the input power into the precise RF and DC voltages. These voltages drive the mass filters and supporting ion optics.

The QPS Exciter Board and the Q1 and Q3 Amplifiers form part of the Quadrupole Power Supply which provides the precise AC and DC voltages to the Q1 and Q3 Mass Filters. Refer to the *Quadrupole Power Supply (QPS)* section described later in this chapter.

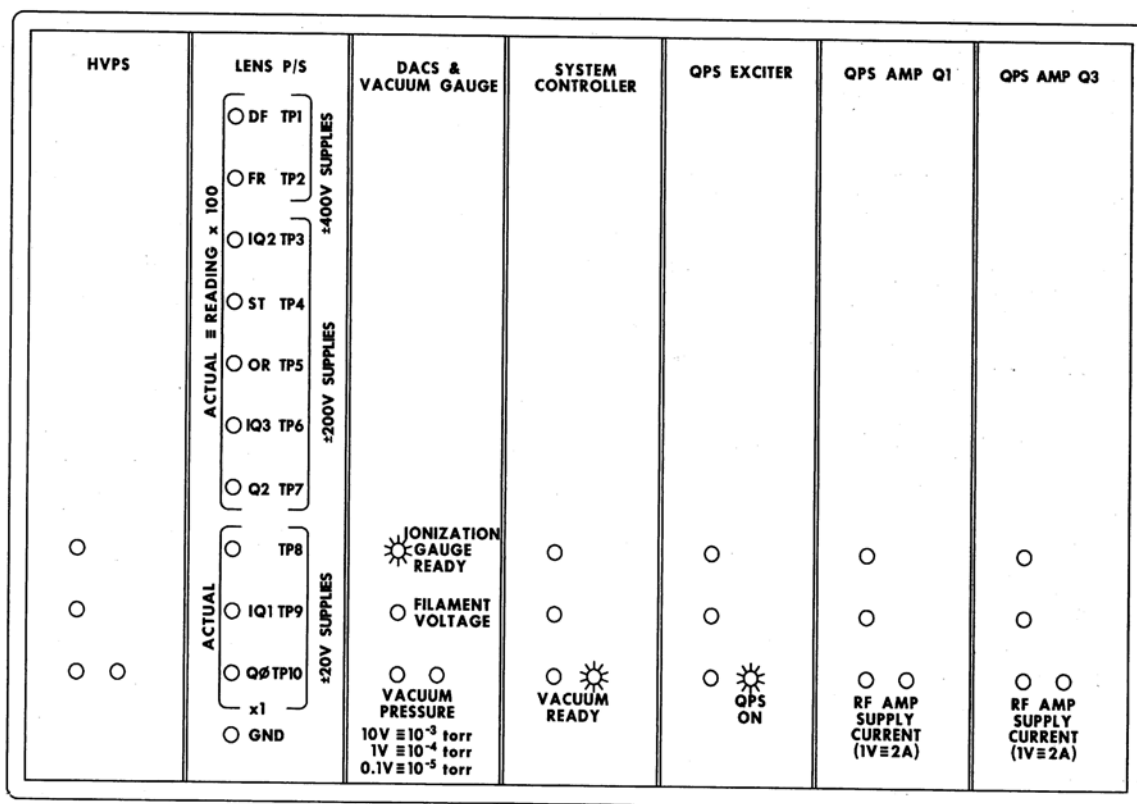


Figure 6-2. System Electronics Box - Layout

### 6.3.1 Motherboard

The motherboard is the interface between the API 2000 equipment and the System Electronics. Conceptually, the motherboard is the instrument's electronic hub, supporting the necessary electrical interconnections between the system's printed circuit boards and the API 2000 main module equipment.

The four DC voltages are connected through the motherboard to the System Electronics Box modules and by detachable cables to the main module equipment.

### 6.3.2 System Controller Module

The System Controller is the focal point for the instrument's high-speed data acquisition and control functions. It uses two highly integrated microprocessors and associated memory chips with embedded software (firmware) to control the operation of the instrument.

The instrument's firmware essentially controls and coordinates all instrument's components and functions, including the ion optics, mass

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filters, collision cells, ion detector, gas flows and vacuum system. In addition, the firmware facilitates the IEEE communication link with the Applications Computer and the RS232 link with external sample introduction devices. The following is a list of the major functions controlled by the instrument's firmware:

- Instrument control
- Scanning and data acquisition
- Preliminary data processing
- Communications to the host computer
- Mass calibration
- Instrument tuning
- Interface to sample introduction devices
- Maintaining configuration tables
- Error handling and reporting

#### **System Controller Design**

The next figure is a block diagram of the System Controller showing the internal and external connections to and from the System Controller. The different digital inputs and outputs, both external and internal, are listed in the System Controller Digital I/O table.

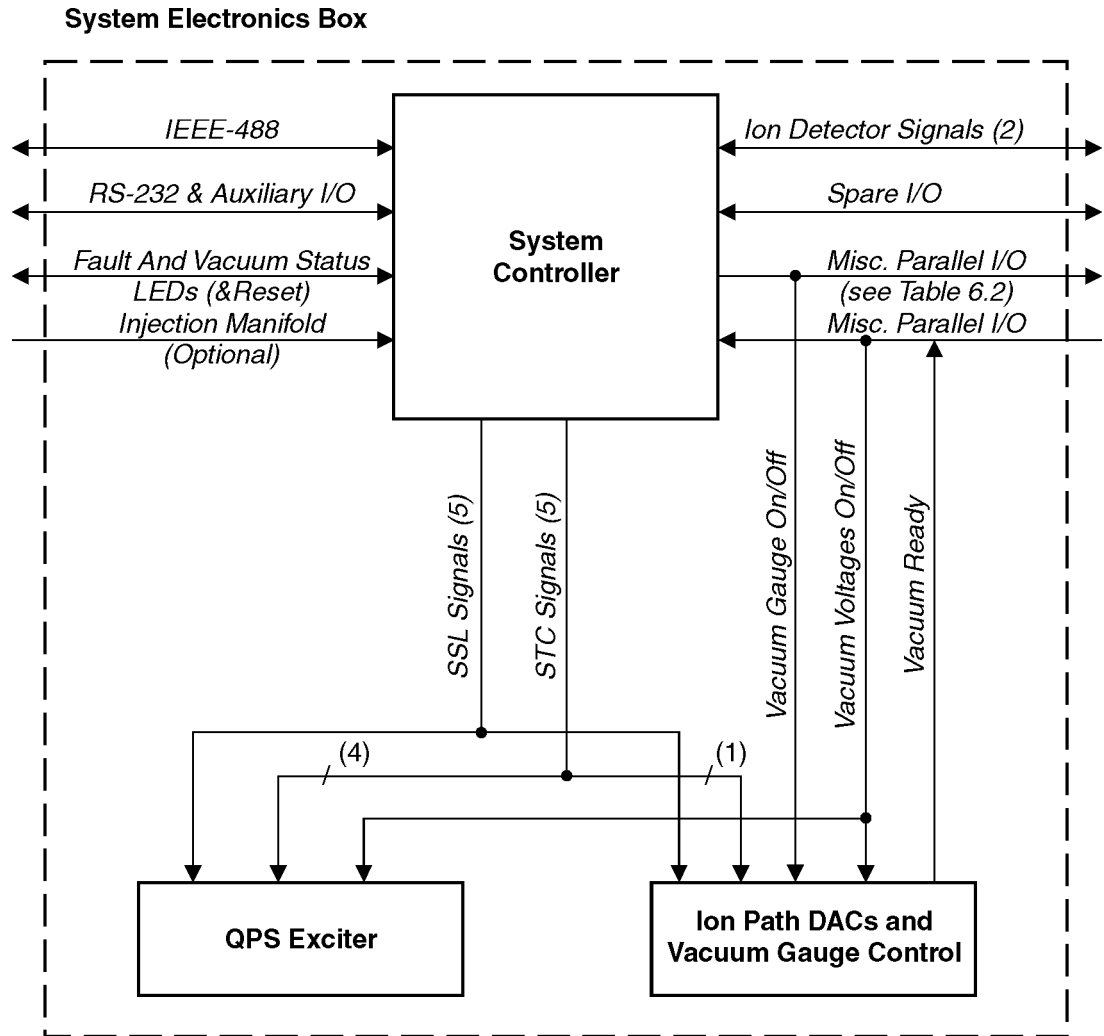


**Figure 6-3. System Controller Interconnect**

Both System Controller microprocessors can be reset via common local LEDs on the Power Module Cover. Resetting the microprocessors is similar to rebooting a computer. It interrupts any ongoing procedures and discards any data in the RAM memory. The System Controller's microprocessors also reset automatically when the +5V Power Supply on the motherboard drops below ~4.6V.

---

*Note* Care should be taken when resetting the System Controller to prevent the loss of unsaved data.

---

The two on-board indicators, a red and a green LED are each driven by one of the microprocessors. The red and green LED reset switches on the Power Module Cover are external representations of the on-board LEDs.

While in reset mode, both LEDs are illuminated; otherwise they revert to firmware control and definition. For more information on LED indicators, refer to the *Vacuum Control System* section in this manual.

**Table 6-1. System Controller Digital I/O**

| Internal                      | External                      |
|-------------------------------|-------------------------------|
| Ion Detector Signal(s)        | IEEE-488                      |
| Synchronous Serial Link (SSL) | RS-232                        |
| Scan Timing and Control (STC) | Auxiliary I/O                 |
| Miscellaneous Parallel I/O    | Injection Manifold (optional) |

**Table 6-2. Miscellaneous Parallel I/O**

| Input                                        | Output                                                    |
|----------------------------------------------|-----------------------------------------------------------|
| Curtain Gas Status                           | Vacuum Gauge On/Off                                       |
| Vacuum Ready                                 | Vacuum Voltages On/Off (includes Interface High Voltages) |
| Interface Pump Status                        | CAD Gas Pressure Control Organ Pipe                       |
| Backing Pump Status                          | Curtain Gas Flow Control Organ Pipe                       |
| DI220 LPS Turbo Pump Status - Normal         | Turbo Vent Valve                                          |
| Sample Interface High Voltage Interlock      | DI220 LPS Turbo Pump On/Off                               |
| Source Exhaust Pump Status (optional)        | Solvent Exhaust Pump On/Off (optional)                    |
| Injection Manifold Valve Position (optional) |                                                           |

### 6.3.3 Internal Functions

The System Controller's main console functions can be divided into two separate, but interrelated functions:

- Data Acquisition
- Instrument Control, Vacuum system and gas flows

#### Data Acquisition

Data acquisition experiments are designed by the operator at the Applications Computer using the TUNE, or Sample Control software (see the *API 2000 Operator's Manual*). When an experiment is designed and initiated, the necessary information is uploaded to the System Controller. From that point, the data acquisition is controlled from the System Controller's firmware. The scan parameters are set and the data is acquired in the format requested. The data is then relayed back to the Applications Computer where it can be displayed as it is acquired, or saved to a specified file to be analyzed later.

---

The firmware is designed so that once a data acquisition method is defined, it can be performed by the firmware without relying on the Applications Computer. As a result, the firmware stores the necessary mass to DAC calibration tables for both the Q1 and Q3 Mass Filters and the defined state files that specify instrument settings.

The firmware not only stores calibration tables, but actually supports an automatic calibration routine. For more information on calibration procedures, refer to the TUNE chapter in the *API 2000 Operator's Manual*. The interactive routine requires the operator to specify the known mass peaks for the sample to be injected. Given that information, the firmware scans for the specified peaks and develops the mass to DAC value tables necessary to interpolate subsequent DAC values and converts them to mass units.

The firmware actually stores two calibration tables: a default table (stored in the non-volatile memory) and an active table (stored in the RAM memory). Either of these calibration tables can be transferred from the System Controller to the Applications Computer where they can be examined and saved.

---

|             |                                                                                                                                                                                               |
|-------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>Note</i> | <i>It is recommended that you save the calibration files in a common file on the Applications Computer disk so that they can be uploaded to the System Controller's memory when required.</i> |
|-------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

---

### **Ion Optics Control**

The System Controller firmware transfers the digital ion path parameter data set at the Applications Computer to the appropriate DACs on either the Exciter board, the Ion Path DAC, or the Vacuum Gauge Controller board. The DACs, in turn, convert the digital signal into a low-level analog signal that is transferred to the Lens Power Supply board, the High Voltage Supply board, or the QPS Amplifier boards for amplification.

The ion path parameters are relayed using the SSL (Synchronous Serial Link), a full duplex serial interface that provides a high-speed data communication link. The SSL signals are not connected directly from the System Controller to each DAC. Instead, each data transfer from the System Controller specifically addresses a particular DAC and is sent to a device on the Exciter board, the Ion Path DACs, or the Vacuum Gauge Controller board. The device decodes the address and relays the data to the preload register on the appropriate DAC.

When prompted by the Time Processing Signal, (refer to the next section on the Time Processing Unit), the data in the preload register is loaded to the DAC. This initiates the change in the ion optic voltages.

### Ion Counting

The System Controller receives a digital signal from the Signal Handling Board, where each digital switch marks the boundary of a single ion pulse (count). For more information on the Signal Handling Board, refer to the *Vacuum Chamber* section in this manual. The System Controller has a counter; in actual fact, two 32-bit counters. One counter is 'active'; the other is 'inactive'. While the active counter counts, the inactive counter is re-transmitting the previous count to the Applications Computer. After successfully transmitting the count data, the inactive counter is cleared, making it ready to become the active counter.

The configuration means that one counter is always available to count. The counters alternate or toggle between active and inactive, leaving no dead time between data measurements.

### TPU (Time Processing Unit)

Both the Ion Counting and the Ion Optics Control functions depend on the Time Processor unit or TPU signal initiated from the System Controller. The TPU consists of five signals that control the sequencing of ion counting and the uploading of ion path DACs. The table below lists the signals and describes how the instrument responds to each signal.

**Table 6-3. Scan Timing and Control (STC) Signals**

| STC Signal        | Description                                                                                                                                                                                                                                                                                                                                            |
|-------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Settling          | Gates on the ion counting/measurement process at a meaningful time, such as after a large jump in mass once the mass filter has settled down. When active high (1), it disables ion counting. When inactive low (0), it enables ion counting. Also, its rising edge sets the QPS Mass DAC (s) to whatever value is in the Mass DAC's preload register. |
| Capture Point     | Its rising edge represents the end of one measurement period (dwell) and the start of the next.                                                                                                                                                                                                                                                        |
| AMU               | Simultaneously updates all Ion Path DACs with the value currently in their respective preload registers. This signal pulses low about once per amu in ramp scan mode.                                                                                                                                                                                  |
| Increment Q1 Mass | Each rising edge increments the Q1 Mass DAC by one LSB. Used in ramp scan mode only.                                                                                                                                                                                                                                                                   |
| Increment Q3 Mass | Each rising edge increments the Q3 Mass DAC by one LSB. Used in ramp scan mode only.                                                                                                                                                                                                                                                                   |

### Instrument Control

The System Controller monitors the status of the vacuum system and the related main console equipment using the Miscellaneous Parallel I/O signals listed in the Miscellaneous Parallel table. As prescribed in the System Controller firmware, the appropriate miscellaneous output signals are triggered depending on the vacuum conditions. The firmware and the miscellaneous I/O signals ensure consistent and predictable vacuum system and gas flow behavior as outlined in the *Vacuum Control System* section in this manual.

---

### 6.3.4 Windows NT and Mac Users

Because Analyst runs on Windows NT, you can operate it in a network environment. This means that you can perform some functions remotely, which can save you time and effort. Analyst functions are divided into five modes: Configure, Tune, Acquire, Explore and Quantitate. You can switch from one mode to another without closing the current mode in which you are working. For more information, see the *Analyst Operator's Guide*.

The Tune mode allows you to:

- Perform mass calibration
- Set auto-tuning on or off
- Perform manual tuning
- Optimize resolution
- Set auto optimize quantitation
- Build a tuning method
- Build a quick single period, single experiment acquisition method

If you are a Mac user, you will notice that in Tune mode you no longer adjust individual lens voltage. YOU now have to specify ion energies that correspond to potential differences between the lenses. For differences between Mac and Windows NT, refer to the *Analyst Operator's Guide*.

To use this function, you must first log into Windows NT. The Navigation bar that appears on the left-side of the Analyst window allows you to use the various modes common to the Analyst software and allows you to quickly access specific functions. When you double-click the icon for a particular mode, the tree expands or collapses to show or hide icons for common functionality within the mode you selected. These icons are shortcuts to options or actions that components can perform.

#### **Tune Software**

The Tune software allows you calibrate and optimize your instrument. The functions includes the following:

- Resolution optimization
- Mass calibration
- Quantitation optimization
- Manual tuning

---

## Mass Calibration

Before you begin mass calibration, you must set the tuning options.

1. From the Tool menu, click **Settings**, then click **Tuning Options**. The Tuning Options dialog box appears.
2. On the Calibration tab, select the calibration standard, PPGs Pos.
3. Select the appropriate polarity, the reference and the appropriate method
4. Click **OK**.
5. Ensure that the Manual Tune icon is active on the Navigation bar.
6. Acquire the data and select the spectrum.
7. On the Navigation bar, click **Calibrate from Current Spectrum**. The Mass Calibration Option dialog box appears.
8. Type the search range, peak width and threshold you want and click the **Reference** button. The Reference Table Edit dialog box appears.
9. Click the appropriate **Use** check boxes to select the masses you want to calibrate and click **Start**. When the mass calibration ends, three graphs are displayed in the Calibration window. The graph and mass shift, shows the difference between the measured masses from the current calibration and the true masses. The peak width graph shows the peak width for each mass. For unit resolution this should be 0.7 amu at half height. The intensity difference graph shows the intensity difference between the previous calibration and the current calibration.
10. In the Calibration Report window, you can:
  - Click the Update button to update the calibration table with the new values. No changes will be made for masses in the existing calibration table that were not calibrated during this operation.
  - Click the Replace button to replace all values in the calibration table with new values from the mass calibration.

## Optimizing the Resolution

Before you begin, set the tuning options for the resolution optimization.

1. Ensure that the Resolution Optimization icon is active in the Navigation bar.
2. Click **Resolution Optimization**. The Auto Resolution Option dialog box appears.
3. Select the calibration standard, PPGs Pos.

- 
4. To select the quadrupole or quadrupoles on which to perform the resolution optimization, select the **Q1** or **Q3** check box, or both check boxes.
  5. To select the resolution or resolutions you want optimized, select the **Unit** or **High** check box, or both check boxes.
  6. Click **Start**. The automatic resolution optimization operation starts and the Automatic Resolution Report begins to appear. When the function is completed, a real-time display of the results of the operation is displayed.
  7. To save the resolution table, click **Yes** in the Save Resolution Table message box.
  8. To complete the operation, click OK in the Auto Resolution message box.

### Optimizing the Quantitation

Quantitation optimization allows you to automatically optimize the instrument for best performance for both the infusion and the flow-injection types of sample inlet. Analyst provides a wizard to aid you in setting up quantitation optimization.

1. Ensure that the Quantitation Optimization icon on the Navigation bar is active.
2. From the Tools menu, choose **Quantitation Optimization**. The Instrument Setting dialog box appears.
3. Select **Infusion** as the inlet type; click **MS Analysis** and then click **Next**. The Ions to use in MS Analysis dialog box appear.
4. Select the polarity. If you select **Both**, Analyst optimizes using both polarities and selects the best polarity for each target compound.
5. Select the resolution from the list.
6. Select the target ion.
  - If you select **Base Peak Ion**, Analyst optimizes one compound only. You can name the compound and edit the search range. The label on the **Next** button changes to Finish. Go to step 9.
  - If you select **MW Ion**, Analyst can optimize more than one compound. Go to the next step.
7. Click **Next**. The Target Components dialog box appears.
8. Type or edit the list of compounds, molecular weights and the number of charges.
9. Click **Finish**. Quantitation starts and the Quantitation Optimization Report is displayed.

---

### 6.3.5 External Connections

The System Controller supports the external links to either the Applications Computer, the injector manifold, or other LC sample introduction equipment. The System Controller Digital I/O table lists the external connections to and from the System Controller.

The IEEE-488 connection from the instrument to the Applications Computer and the RS-232 and Auxiliary I/O port connections on the I/O panel are primarily used to coordinate real-time activities between the instrument and other LC sample introduction and detection devices. The Injection Manifold is optional.

### 6.3.6 Ion Path DACs and Vacuum Gauge Controller Module

The Ion Path DACs and the Vacuum Gauge Controller board have two distinct functions:

1. To provide reference voltages for control of the Ion Path, Ion Source and ETP Power Supplies.
2. To provide power and control for the Vacuum Gauge.

If your system has the Heated Nebulizer option, this board performs a third function, which is to provide control of the Heated Nebulizer Temperature Controller.

#### **Ion Path DACs**

The Ion Path DACs convert the digital signals containing the ion path voltage data into low-voltage analog control signals. The analog signals are sent to the Ion Path Power Supplies on the Lens Power Supply board, the Ion Source and the ETP Power Supplies on the HV Power Supply Board where they are amplified to their target voltage.

Seven dual-output DACs with 12-bit resolution produce the output analog voltages. Five of the DACs are configured for bipolar operation (-5V to +5V), while the other two are configured for unipolar operation (0V to +10V). An internal +5V reference is used for all DACs and is also passed off-board to provide a fixed reference voltage for the ETP Power Supply. A relay is used to disconnect the +5V reference voltage that zeros the outputs of the DACs in response to the Reference Enable signal. Zeroing the DAC outputs sets the ion optic voltages to zero.

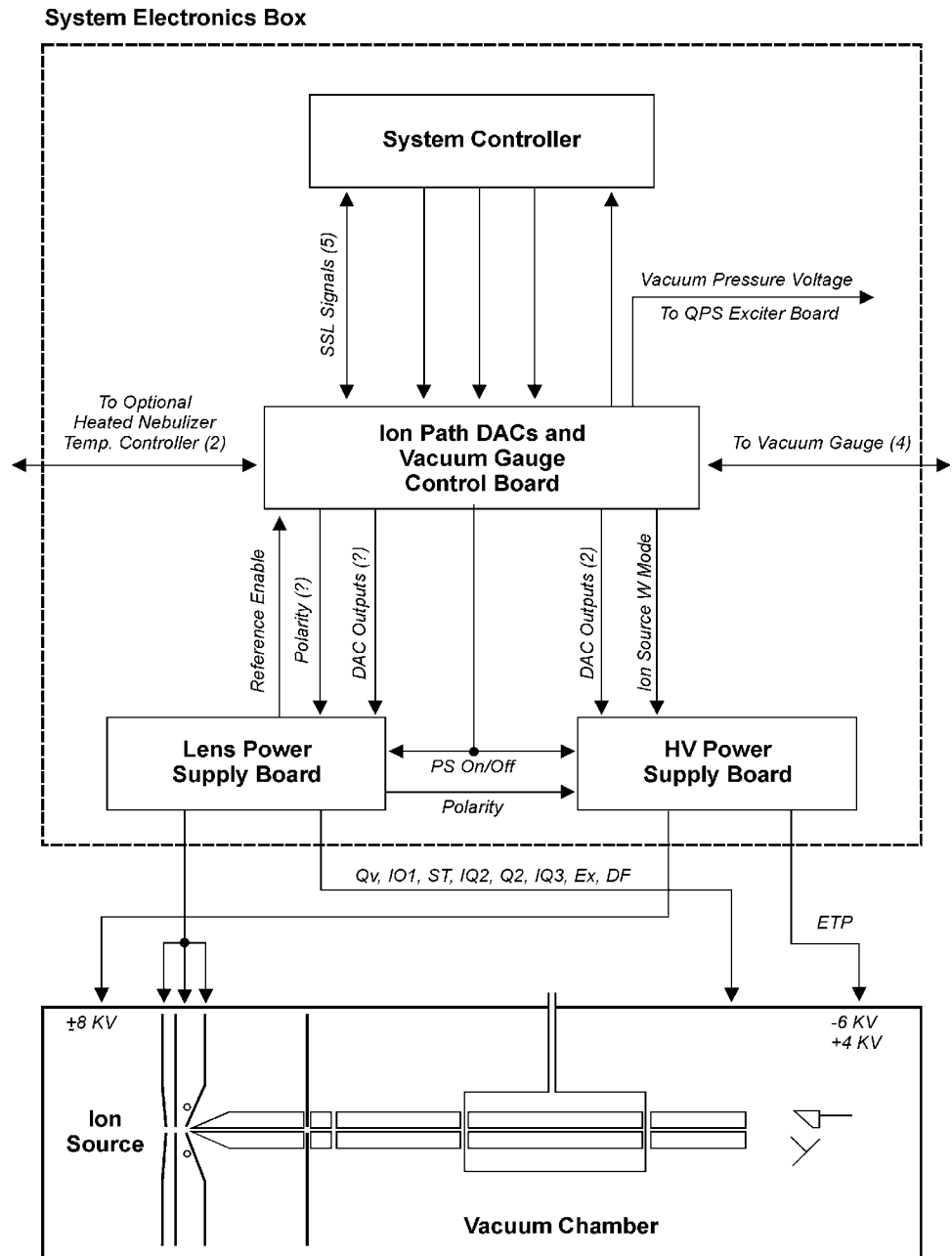


Figure 6-4. Ion Path/HV System Interconnect

#### Vacuum Gauge Controller

The Vacuum Gauge Controller enables power to the filament inside the Vacuum Gauge in response to a signal from the System Controller. The Vacuum Gauge is enabled when both Turbo Pump Controllers reach normal operating conditions (usually below  $10^{-3}$  torr). The operation of the

Vacuum Gauge is described in the *Vacuum Control System* section in this manual.

The power supply for the filament is +6.5 VDC from the Main DC Power Supply. The actual voltage applied to the filament is regulated to ensure that an electron emission current of 0.1 mA is maintained. The voltage required to maintain the electron emission current increases as the vacuum gauge ages. When the voltages reach 6.0V, the gauge should be replaced. For information on replacing the Vacuum Gauge, refer to the *Vacuum Control System* section in this manual.

### 6.3.7 Lens Power Supply Module

This board supplies all the DC voltages required by the ion optics, excluding the ion path voltages that are part of the QPS (for example, Q1 and Q3 Rod Offsets).

Eleven power supplies are required in total (see the Scan Timing and Control (STC) Signals table), all of which are computer adjustable with the exception of the Curtain Plate Power Supply that has a fixed output. There is also sequencing logic to control polarity reversals that occur when the polarity of the ion to be analyzed is switched.

The adjustable power supplies are actually configured as amplifiers whose inputs are the low-level analog voltages from the appropriate DAC on the Ion Path DACs and the Vacuum Gauge Controller board. The amplifiers are powered by rail voltages of  $\pm 530V$  and  $\pm 270V$  generated by a switching DC-to-DC converter. The DC-to-DC converter also produces a polarity-reversible 1100V output for the Curtain Plate Power Supply.

Test points are provided on the front panel of the module for all adjustable lens voltages.

**Table 6-4. Lens Power Supply Ranges**

| Component        | S/W Mnemonic | Power Supply Name | Power Supply Range  |
|------------------|--------------|-------------------|---------------------|
| Curtain Plate    |              |                   | $\pm 1K$ VDC, fixed |
| Orifice Plate    | OR           | 200VPS1           | $\pm 200$ VDC       |
| Focusing Ring    | RNG          | 400VPS3           | $\pm 400$ VDC       |
| Q0 Rod Offset    | Q0           | 22VPS1            | -22 to +22 VDC      |
| Interquad Lens 1 | IQ1          | 22VPS2            | -22 to +22 VDC      |
| Stubbies         | ST           | 200VPS1           | $\pm 200$ VDC       |
| Interquad Lens 2 | IQ2          | 200VPS1           | $\pm 200$ VDC       |
| Q2 Rod Offset    | Q2           | 200VPS1           | $\pm 200$ VDC       |
| Interquad Lens 3 | IQ3          | 200VPS1           | $\pm 200$ VDC       |
| Deflector (DF)   | DF           | 200VPS1           | $\pm 400$ VDC       |

---

The lens power supply sequencing logic is programmed to disable the switching converter and zero the amplifier reference voltages from the ion path DACs on initial power-up and during ion polarity reversal. In addition, the ion path DAC output reference voltages are disconnected under the following conditions:

- a. In response to the Power Supply Enable signal (Vacuum and Safety Interlock Dependent)
- b. For approximately two seconds allowing an ion polarity reversal
- c. For approximately one second following power-up of the +24V supply

### 6.3.8 HV Power Supply Module

This module contains three distinct power supplies that provide two high voltages for the ETP (bias and float) and the voltage Ion Source. The Ion Source power supply provides the high voltage required by the IonSpray Inlet and, if the Heated Nebulizer is installed, the high voltage for the corona discharge needle. The ETP bias voltage and the Ion Source voltages are set at the Applications Computer.

The HV Power Supplies use the +5V reference voltage derived from the Ion Path DACs and Vacuum Gauge Control board as a base reference.

Each power supply uses a power amplifier and a step-up transformer to generate a high voltage AC waveform from the low-level DAC output voltage. The AC voltage is then converted to a DC output voltage by a bipolar voltage multiplier.




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**WARNING**     *Wait one minute after powering down before removing modules from the card cage. Nonhazardous high voltage is still present in the back plane of the module one minute after powering down the instrument.*

---

#### ETP Float Voltage Supply

The ETP Float Voltage Supply is fixed depending on the polarity of ions being analyzed. For positive ions, the voltage is -6000V; for negative ions, the voltage is fixed at +4000V. This voltage comes from the HV Power Supply Module.

The divider network is used to provide a low voltage test point for the ETP voltage. By using 1000 M $\Omega$  (R7) and 1.1 M $\Omega$  (R6), the divider ratio is set approximately 1000:1. This ensures that the test point is adequately accurate when running diagnostics.

The noise on the signal due to the ripple on the ETP+ terminal can be reduced by adding a simple RC filter (R3//C3) in series.

---

### **ETP Bias Voltage Supply**

The ETP Bias Voltage Supply creates the potential gradient. The bias voltage is applied to the end of the detector opposite the horn. It is set between 2000 - 3000 V more positive than the horn voltage. Therefore, ETP+ is equal to the sum of ETP- and bias voltage. The bias detector voltages are supplied from the HV Power Supply Board. Similar as the ETP-divider network, R4 and R1 are used to provide a divider approximately 1000:1.

### **Ion Source Power Supply**

The Ion Source Power Supply generates a variable DC output between 0kV and 8kV in either polarity. It operates in voltage-regulated mode with the IonSpray Inlet. With the Heated Nebulizer, the voltage is adjusted to control the current flow between the corona discharge and the Curtain Plate.

## 6.4 Quadrupole Power Supply (QPS)

The QPS generates the precise DC and RF voltages that drive the mass filters Q1 and Q3. It is designed for high stability and accuracy and consists of two coil boxes, two Amplifier Boards and a common Exciter Board (see the figure below).

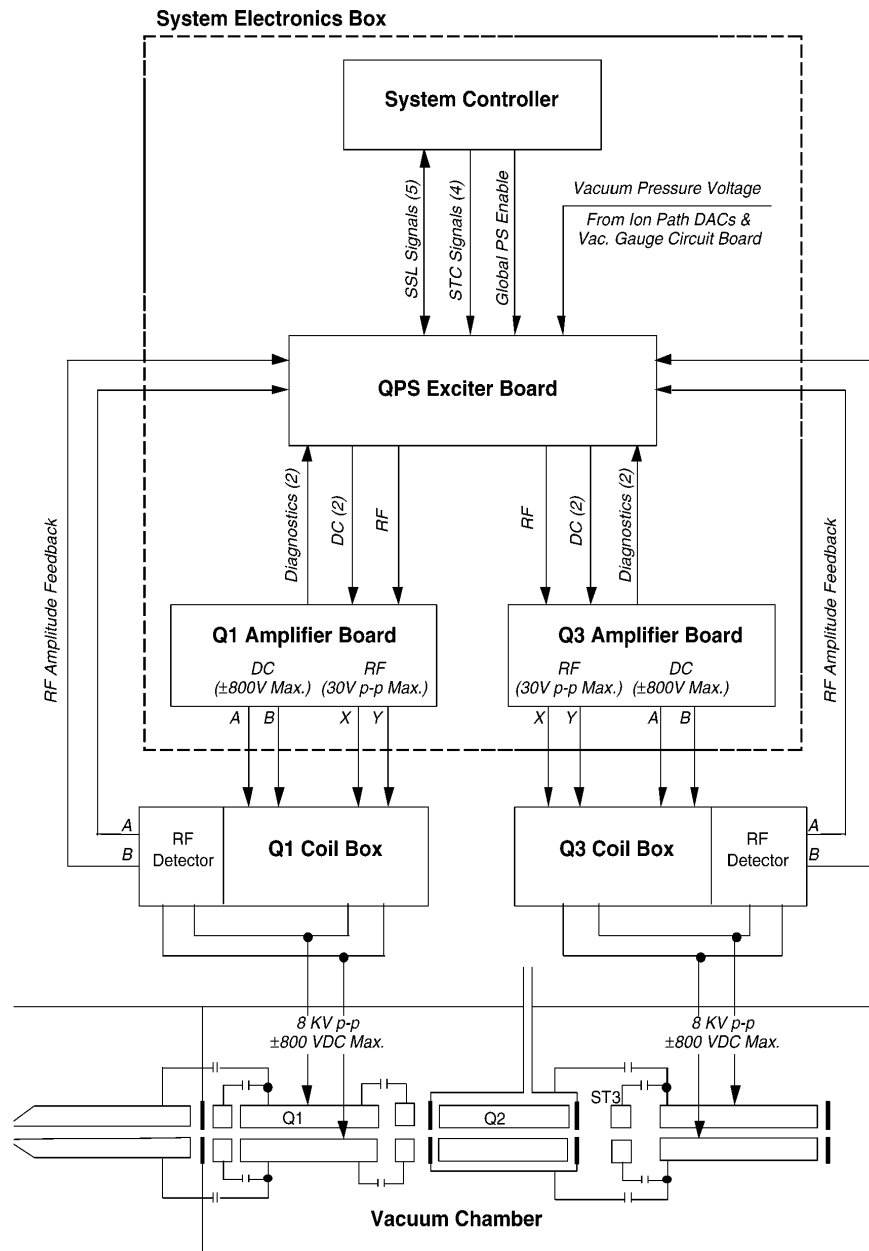


Figure 6-5. QPS System Interconnect

### 6.4.1 Exciter Board

The Exciter Board generates the source DC and RF voltages that are relayed to the appropriate Q1 and Q3 Amplifier Module for amplification. The Exciter Board consists of two sections: digital and analog.

#### Digital

The principal function of the Exciter Board's digital electronics is to relay the QPS digital data received over the SSL to the on-board DACs for conversion to a low-level analog signal. The following ion path parameters are processed on the Exciter Board:

- Q1 and Q3 Mass DACs (16-bit)
- Q1 and Q3 Rod Offset DACs (dual, 12-bit)
- Q1 and Q3 Resolution DACs (dual, 12-bit)
- RF Mode Setting
- Power Supply Enable

The low level analog DAC output signals are then relayed to the Q1 and Q3 amplifier modules for amplification.

The QPS, RF and DC output voltages can be switched "ON" or "OFF" at the Exciter Board by the Global Power Supply signal. Switching off the Global Power Supply disables the RF and DC output voltages locally. The Global Power Supply signal is under firmware control and will automatically switch off the QPS voltages if operating vacuum conditions or safety interlocks are breached.

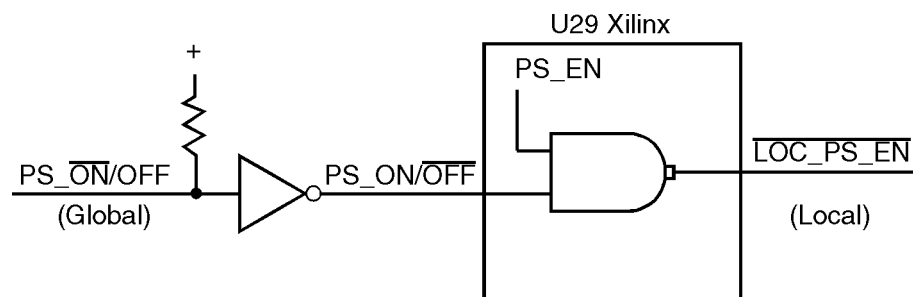


**Figure 6-6. Power Supply Enable Logic**

As a result, the following physical conditions must be satisfied for the QPS RF and DC voltages to be on:

1. System Controller Global Power Supply output bit/line set to ON (zero volts).
2. Sample Inlet Housing installed to satisfy mechanical interlocks.
3. Power Supply Enable bit set (logic high/one) via the SSL.

---

### **Analog Portion**

The Exciter Board's analog circuitry produces the precise low-level mass filter RF voltages that are amplified at the Q1 and Q3 Amplifier modules and coil box assemblies. It is the precision of the QPS voltages that is the basis of the enhanced performance characteristics of the API 2000 mass spectrometer.

The analog circuitry contains thermally sensitive elements and as a result is enclosed in a thermally isolated, temperature stabilized oven. The oven is heated by four power transistors that are bolted to the oven extrusions. The temperature is monitored and a feedback circuit drives a power transistor that maintains a constant temperature in the oven.

The analog circuitry is powered by four IC voltage regulators independent of the DC Power Supply. This ensures that noise from the DC Power Supply does not corrupt the sensitive QPS electronics. The voltage regulators produce  $\pm 12$  VDC and  $\pm 15$  VDC outputs.

The RF signals are developed from a 816 kHz signal generated by a crystal oscillator. The active element in the oscillator is a current mode amplifier that produces a sine wave output. The signal is filtered and then split to provide drive signals for both mass filters. The separate Q1 and Q3 RF signals are then applied to a multiplier stage that sets the RF signal level depending on the Q1 and Q3 mass DAC outputs.

The actual RF voltage applied to the mass filters after amplification is detected and used in a negative feedback loop that nullifies the gain variations of the RF amplifiers and coil assemblies. The RF voltage is measured at the back of the coil boxes by the RF detector boxes and compared with the output of the appropriate Q1 and Q3 mass DAC. The RF signal adjusts to ensure the accuracy of the RF voltage applied to the mass filters.

### **6.4.2 Amplifier Boards**

The Amplifier Boards condition and amplify the RF and DC signals received from the Exciter Board and pass them to the coil boxes. There are two identical Amplifier Boards, one for Q1 and the other for Q3. Each contains an RF stage and a DC stage.

The RF amplifier output stage consists of 4 amplifiers arranged as a parallel push/pull circuit. The amplifiers are powered by two IC voltage regulators. The maximum output RF voltage is 30V peak-to-peak. This is relayed to the coil box for final amplification.

The DC output stage consists of two DC amplifiers that use six series-connected FETs to produce the required output voltage. The gain of the DC amplifiers is controlled by a precision voltage divider, with a low temperature coefficient. The circuitry of the two DC amplifiers differ slightly. One has a +200V offset capability and the other has a -200V offset

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capability. The amplifiers have an output swing of over 800V. The outputs are short-circuit protected.

### **6.4.3 Coil Boxes**

The coil boxes are the final stage in amplification. Each coil box is an EMI-tight enclosure that contains resonating coils, tuning elements and RF voltage sensing components. The resonating coils have an RF voltage gain of 275 that increases the voltage up to the 8000V peak-to-peak required by the mass filters.

The high-voltage RF leads from the coil boxes to the mass filters are connected via feedthroughs that are mounted underneath the Vacuum Chamber. The RF leads are connected after the Mass Filter Rail is installed inside the Vacuum Chamber. For more information, refer to the *Vacuum Chamber* section in this manual.

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## 6.5 System Electronics Box Circuit Descriptions

The System Electronics Box houses the seven PC board modules. It is assembled separately and mounted as a unit to the chassis. Each of the board modules slides into the Systems Electronics Box and plugs into the motherboard that forms the back wall of the box. The API system's main module equipment is linked to the system's PC boards via detachable cables that plug into the rear of the motherboard.

The Card Cage Blower is bolted to the bottom of the System Electronics Box and connected to the AC Distribution Board via cable AC P3 through the back of the box frame.

Each of the seven PC Boards are mounted in the System Electronics Box in separate modules designed to minimize electro-magnetic radiation and susceptibility hazards.

The modular design of the PC boards simplifies field service procedures. Should one of the system PC boards require replacement, the complete module can be replaced in minutes. The defective board should be returned to the factory for repair.

---

|                |                                                                                                                                     |
|----------------|-------------------------------------------------------------------------------------------------------------------------------------|
| <b>Caution</b> | <b><i>Do not remove any of the system modules with the instrument switched on. Doing so will damage the system electronics.</i></b> |
|----------------|-------------------------------------------------------------------------------------------------------------------------------------|

---

### 6.5.1 Motherboard

The motherboard is the interface between the LC2 equipment and the System Electronics. Conceptually, the motherboard is the instrument's electronic hub, supporting the necessary electrical interconnections between the System's PC boards and the LC2 main module equipment.

The motherboard receives +5.0V, -18V, +24V A and +24V B inputs from the DC Power Supply. A fourth 5 VDC supply is produced on the motherboard, from the 6.5V input. The four DC voltages are connected through the motherboard to the System Electronics Box modules and by a detachable cable to the main module equipment.

#### **Motherboard Circuit Description**

The regulator U1 provides a 5 VDC output from the 6.5V input from the DC Power Supply. It is heat sunk to dissipate 3 amps of continuous current. Capacitors C7 and C8 shunt to ground any voltage surges on the 6.5V input and the 5V output from U1.

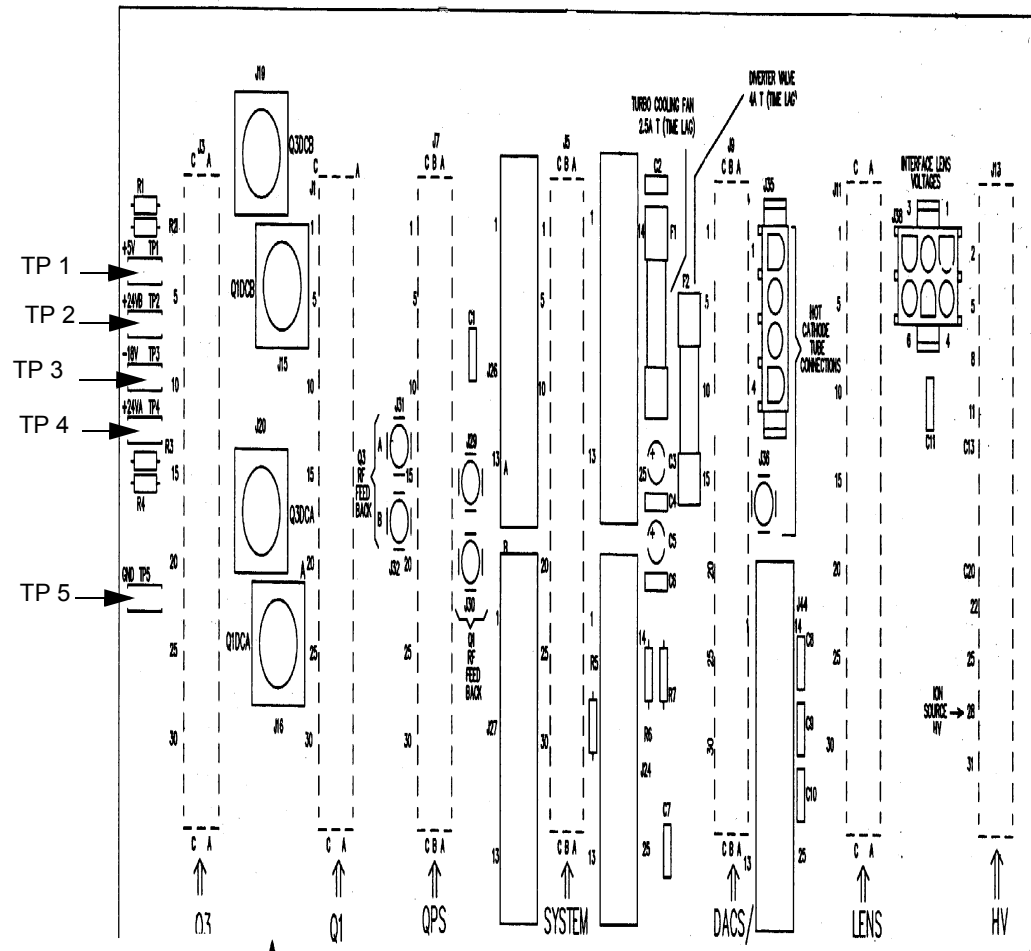


**Figure 6-7. Motherboard**

Resistors R1 and capacitors C1 and C2 reduce the 24V input to the +VIN voltage that is relayed to regulator U4 on the Signal Handling Board. Similarly, resistor R4 and capacitors C3 and C4 reduce the -18V input to -VIN that is relayed to regulator U1 on the Signal Handling Board. The 24 and -18 DC voltages are reduced on the motherboard to limit the heat dissipation demands on the confined Signal Handling Board, where the +VIN and -VIN voltages are regulated to produce +5V and -5V supplies.

#### Test Points

The motherboard has five test points on the upper left back corner of the board for confirming the 4 DC voltages. The test points and the outputs for each are listed below. The voltages as measured on the motherboard

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should fall within 2% of the nominal voltage over the life of the machine in varying operating environments and under different load conditions. Test point five is grounded and is the reference against which the other voltages are measured.

- TP1+5V
- TP2+24 V B
- TP3-18V
- TP4+24V A
- TP5ground

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|             |                                                                                                                     |
|-------------|---------------------------------------------------------------------------------------------------------------------|
| <i>Note</i> | <i>A list of motherboard external cable connections and pin assignments is provided at the end of this chapter.</i> |
|-------------|---------------------------------------------------------------------------------------------------------------------|

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## Replacing the Motherboard




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|                |                                                                                                                                                                                                                                                        |
|----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>WARNING</b> | <b>BIOHAZARDOUS MATERIAL</b> <i>Do not dispose of system components or subassemblies, including computer parts, in municipal waste. Dispose of replaced components and instruments according to established waste electrical equipment procedures.</i> |
|----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

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1. Shut down the instrument.
2. Open the Source Cover.
3. Remove the Back Cover.
4. Open the Front Cover.
5. Disconnect the gas fitting from the rear flange and allow the Vacuum Chamber to vent.
6. Remove all modules and all connections from the back of the motherboard.
7. Remove the seven PC board modules from the System Electronics Box.

---

|                |                                                                                                                                            |
|----------------|--------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Caution</b> | <b>Ensure the main power supply is off. Disconnecting the system PC boards with the power on will damage the instrument's electronics.</b> |
|----------------|--------------------------------------------------------------------------------------------------------------------------------------------|

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8. Remove the clamp that connects the vacuum gauge elbow to the Vacuum Flange.

- 
9. Disconnect the cable linking the DI220 controller to the DI220 turbo pump.
  10. Disconnect the two wires from the backing pump sensor.
  11. Remove the clamp attaching the vacuum port to the exhaust port of the DI220 turbo pump. Rest the vacuum line on the bench supporting the instrument.
  12. Carefully snip the two cable ties that secure the Curtain Gas tubing to the top of the motherboard.
  13. Snip the three cable ties clamping the following cables to the motherboard:
    - Interface and Ion Source Voltages
    - Ion Source HV Extension Cable
    - ETP @ Control Panel
    - ETP Bias Voltage
  14. Snip the two cable ties clamping the RF feedback cables (connectors J29, J30, J31 and J32) to the motherboard.
  15. Disconnect all the external connections to the back of the motherboard.
  16. Remove the 20 Phillips screws that attach the motherboard to the Card Cage assembly and remove the motherboard.
  17. Position the replacement motherboard against the Card Cage assembly and replace the 20 screws.

---

|             |                                                                                                                           |
|-------------|---------------------------------------------------------------------------------------------------------------------------|
| <i>Note</i> | <i>Ensure that the five tie screw mounts #6 are in place as shown in the System Electronics Box - Motherboard figure.</i> |
|-------------|---------------------------------------------------------------------------------------------------------------------------|

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### 6.5.2 System Controller

The next figure is a block diagram of the System Controller. Intercommunications between the 68332 and 68340 microprocessors utilize a 4 kB dual port RAM (U29). Either microprocessor can independently read or write to any location in this memory.

Both microprocessors can be reset via a common local switch (SW1) on the System Controller or by activating the two LED reset switches on the Power Module Cover. If the +5.0V power derived from the +6.5V power supply drops below ~4.6V, both microprocessors will reset. All other reset scenarios, such as firmware reset instruction, affect only the relevant microprocessor.

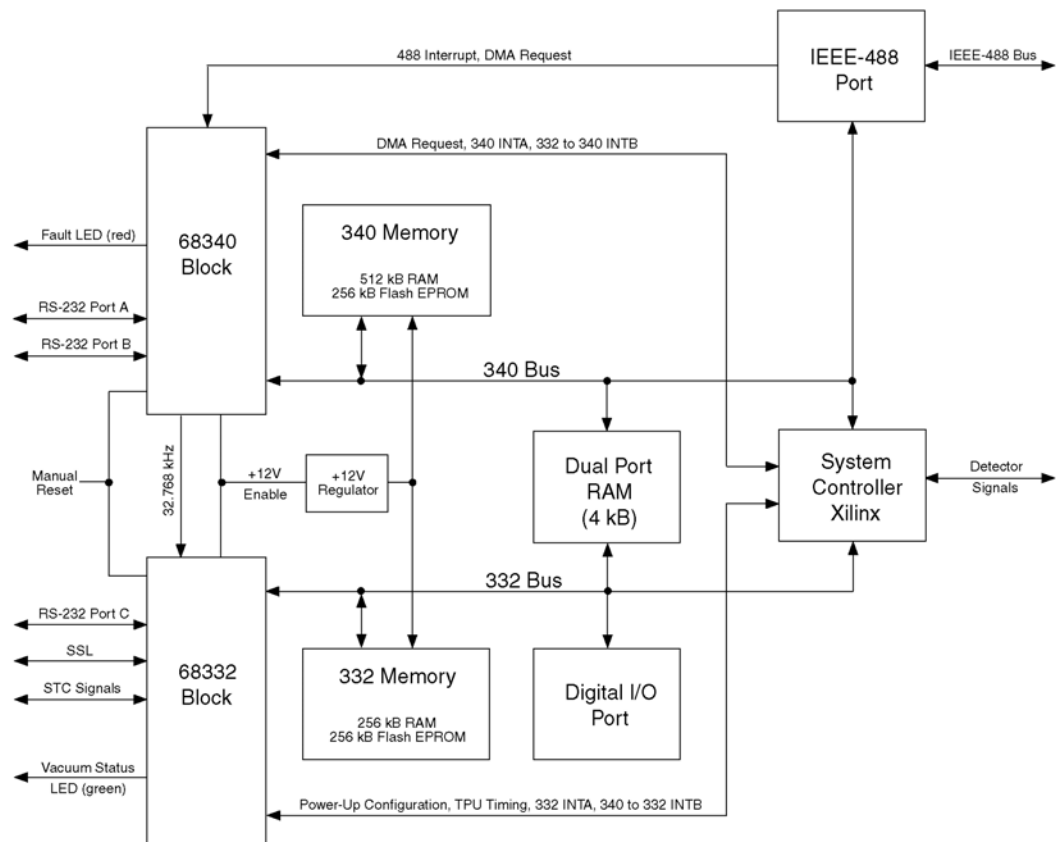


**Figure 6-8. System Controller Block Diagram**

Two on-board indicators, a red LED (DS1) and a green LED (DS2), are driven from the 68340 and 68332 respectively. While in reset mode, both LEDs are illuminated, otherwise they revert to firmware control and definition. The read and green LED reset switches on the Power Module Cover are an external representation of the DS1 and DS2 indicators.

The microprocessor system clock (SCK) is generated by an on-chip, phase-locked loop circuit used to run the device up to 16.78 MHz from a 32.768 kHz crystal. To minimize potential noise, the 68340 microprocessor contains the oscillator circuitry into which the 68332 taps for its 32.768 kHz source.

The microprocessor's RAM consists of 128 kB static devices organized into banks of 256 kB. The 68340's memory consists of two such banks, while the 68322's memory contains only one. All RAM operates with zero wait states and is both byte and word addressable.

Non-volatile memory consists of 128kB flash EPROM devices organized into a bank of 256kB. This memory operates with one wait state and is word

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addressable only. It is used to store firmware, Xilinx configuration data and other miscellaneous configuration information. The Flash EPROMs require 12V for erasing and programming. This voltage is derived from +24V via a linear regulator (U3) that can be switched on (+12V) or off (~1.35V) from either microprocessor.

### **68332 Microprocessor**

The 68332 processor is a 132-pin device used for:

1. Controlling the Vacuum System and Sample Introduction (that is, most internal digital I/O, not including Ion Detector signals)
2. Controlling data acquisition.

In general terms, the 68332 contains:

- A 68020-like CPU operating at 16.78 Mhz
- A highly specialized micro-coded counter/timer, the Time Processor Unit (TPU) and 2kB of RAM assigned to the TPU
- A high-speed synchronous serial port, Queued Serial Peripheral Interface (QPSI)
- One conventional serial port, “C”
- Miscellaneous system integration logic

Digital I/O interfaces to the 68332's bus via U23 and U24 form an 8-bit port occupying four contiguous addresses. Thirty-two discrete digital outputs are provided. The state of each output is controlled by the value written to a flip-flop contained in one of ICs, U6, U16, U18, or U25 regulators that are all forced to zero (logic low) by resetting. Twenty-two CMOS (5V) logic inputs from the input portion of the digital I/O. Each input includes a  $4.7k\Omega$  pull-up to +5V, series  $10k\Omega$  input protection and a  $0.1\mu F$  capacitor for noise suppression.

Data acquisition control relies heavily on the TPU and QSPI. Five TPU signals are used for Scan Timing and Control (see the Scan Timing and Control (STC) Signals table), while the QSPI is a submodule used to control the Synchronous Serial Link (SSL).

The SSL is a full duplex, serial interface that provides a simple, high speed, communication link between the System Controller and the Ion Path electronics. It is primarily used to transfer ion path-related data, such as Q1/Q3 rod offsets, lens voltages and polarities. The SSL also monitors and controls the following signals:

- QPS status
- IonSpray voltage setting
- Heated Nebulizer temperature setting (optional)

- 
- Heated Nebulizer temperature status (optional)
  - Ion Source current setting (optional)

RS-422 differential drivers and receivers are used to condition these signals where they exit or enter the System Controller board.

#### **68340 Microprocessor**

The 68340 processor is a 144-pin device responsible for:

1. Communications between the Main Console and the Applications Computer via IEEE-488.
2. Processing data acquirers measurements results (that is ion counting).

The 68340 shares the same general architecture and CPU core as the 68332. In summary, it contains:

- A 68020-like CPU operating at 16.78 Mhz
- A two-channel Direct Memory Access (DMA) controller
- Two conventional serial ports, “A” and “B”
- Two general purpose 16-bit counter/timers
- Miscellaneous system integration logic

The two-channel DMA controller is used to minimize real-time demands imposed by the IEEE-488 link and incoming ion pulses. One DMA channel is committed to the IEEE-488 port and the other to the System Controller’s Xilinx device that is set up for data acquisition.

The Xilinx device is a Field Programmable Gate Array (FPGA) that is a high-density, application specific IC that does not require custom factory configuration. It consists of many uncommitted, digital devices which, when interconnected for a particular application, form a custom circuit. The principal role of the System Controller’s Xilinx device is a conduit for incoming measurement results for the Ion Detector. As a function of STC signals “Capture Count” and “Settling” from the 68332, it transfers measurement results via DMA or an interrupt request. Since Xilinx technology is SRAM based and therefore volatile, it must be configured upon each power-up. This Xilinx device is configured by the 68332 processor via its Port E, bits 4, 5 and 6, in accordance with the Xilinx Slave Mode Bit Serial protocol.

The IEEE-448 interface is implemented using Texas instruments. National Instruments 9914A controller (U49) and 488 Interface chips (U50 and U59) are miscellaneous logic. The very slow (2-wait state) controller that functions as a talker or listener can interrupt the 68340 and/or generate DMA requests to one of the 68340 DMA channels.

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The two serial ports, A and B, connect from the 68340 to the board's edge via the RS-232 driver and receiver pairs within U39 and U52. Port A, which includes CTS and RTs control lines, is routed to the outside of the Main Console.

Unlike the 68332, the 68340 has very few chip select lines. To produce the required number and type of chip select/control lines, two 16V8 PALs, U47 and U45 regulators are utilized. U46, a simple 8-bit comparator, is used to derive the optional co-processor chip select.

### 6.5.3 Ion Path DACs and Vacuum Gauge Controller

#### Ion Path DACs

The Ion Path DACs send low voltage analog control signals to the Ion Path Power Supplies on the Lens Power Supply Board and to the Ion Source and ETP Power supplies on the HV Power Supply Board.

Seven dual-outputs DACs with 12-bit resolution provide the required reference voltages. DACs U12-14, 17 and 20 are configured for unipolar operation (0V to +10V). The internal +5V reference of U12 is used for all DACs and is also passed off-board to provide a fixed reference voltage for the ETP Power Supply. PhotoMOS relay U9 is used to disconnect the reference, zeroing the outputs of all DACs in response to the Reference Enable signal.

A Xilinx FPGA provides decoding of the address and data instructions sent over the SSL to set the DAC values. DAC data and address codes are received over the SSL from the System Controller. U1-3 are bus receiver/transmitter devices used to interface with Xilinx U6. U6 decodes the serialized address and provides parallel data, chip select and strobe to set up the parallel loading DACs. U4 is a serial PROM that configures Xilinx U6 on power up. U6 also generates signals to enable the High Voltage and Ion Path Power Supply to select current or voltage controlled mode in the Ion Source Power Supply and to switch the polarity of the power supplies.

#### Vacuum Gauge Controller

The Vacuum Gauge Controller enables power to the filament inside the Vacuum Gauge in response to a signal sent by the System Controller when both Turbo Pump Controllers reach normal operating conditions. The Vacuum Gauge Controller provides the signal to turn on the vacuum electronics once the pressure reaches  $10^{-4}$  torr. If, at any time, the pressure exceeds  $10^{-3}$  torr, the Vacuum Gauge Controller turns off the Vacuum Gauge to protect the filament.

The power supply for the filament is 1.5 VDC to 3.5 VDC from the DC Power Supply through the motherboard. The filament is regulated to provide an electron emission current of 0.1 mA. The next figure is a schematic of the Vacuum Gauge Control Circuit.

A Gauge Enable signal from the System Controller enables power to the Vacuum Gauge filament by resetting flip-flop U19b and enabling gate U16b. This turns off Q5, unclamping the Q1 gate and allowing the control loop to regulate the filament current. R41 and C46 provide a soft-start, slowly turning on Q1 to minimize the drop in the 3.5V power supply.

The electron emission current is measured at the grid electrode. With a 0.1 mA emission current flowing through R13, the grid voltage is +150V. The emission current is regulated by the error amplifier U11b and the integrator U11a.

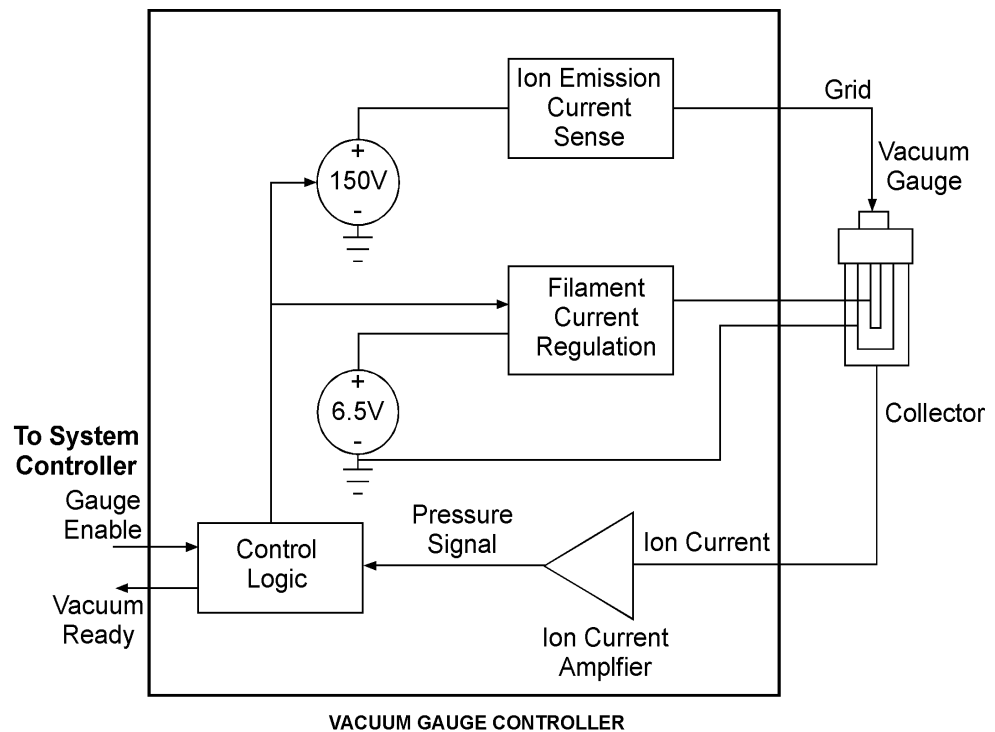


**Figure 6-9. Vacuum Gauge Controller Circuit Schematic**

The ion current is collected at -15V, generating a voltage across R25. This differential voltage is amplified by the instrumentation amplifier U10, whose gain is set to 10 by R19. The overall gain of the amplifier is 107V/A yielding an output signal of 104V/torr ( $1\text{V} = 10^{-4}\text{ torr}$ ).

U15a and U15b act as window comparators to verify that the control loop is in regulation, as indicated by LED D21. If the control loop is in regulation and the pressure is below the operating set point, U18a generates the Vacuum Ready signal to enable the ion path voltages. U18b monitors for the over-pressure fault condition and will set U19 if the pressure exceeds

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$10^{-3}$  torr, turning off the filament power. The gauge can only be restarted by toggling the Gauge Enable signal to reset U19.

The filament voltage required to operate at an emission current of 0.1 mA varies considerably from gauge to gauge, but is normally in the range of 1.5V to 3.5V. As the Vacuum Gauge ages, or if the filament becomes contaminated, the filament voltage will increase to compensate. Once the voltage reaches about 3.5V, the circuit will no longer be able to regulate the emission current. Under this condition, the indicator LED on the front panel (D21) will not light when the gauge is enabled. At that point, the vacuum gauge requires replacement.

A second power supply generates the high-voltage bias for the grid electrode. U1a is configured as a square-wave oscillator at approximately 13 kHz. The AC output is stepped up to 215 VDC by 6 times the voltage multiplier and then zener-regulated to 200V and filtered for the grid supply. The oscillator is disabled by Q2 when the Vacuum Gauge is turned off. U7 and U9 provide regulated  $\pm 15$ V to the board.

#### 6.5.4 Lens Power Supply Board

Eleven power supplies are required for this board. All power supplies are computer adjustable except for the Curtain Plate Power Supply that has a fixed output. Sequencing logic to control polarity reversal for the power supplies' polarity reversal is also provided.

The adjustable power supplies are configured as amplifiers whose inputs are low-level DAC reference voltages. These amplifiers are powered by rail voltages of  $\pm 530$ V and  $\pm 270$ V generated by a switching DC-to-DC converter. Test points are provided on the front panel of the module for all adjustable lanes voltages. The switching converter also supplies rail voltages to the DC amplifiers on the QPS Amplifier Boards.

The low voltage amplifiers are high voltage amps configured as non-inverting amplifiers with a gain of 5. Short circuit protection is provided by a 10K current-limiting resistor. Front panel test points are made through another 10K resistor.

The power supply sequencing logic is required to disable the switching converter and zero the amplifier reference voltages on initial power-up and during polarity reversal. U1 provides a local +5V supply for the sequencing logic. Q1 disconnects the reference from the lens power supply DACs to set all outputs to zero under the following conditions:

1. In response to the Power Supply Enable signal.
2. For approximately two seconds following an ion polarity reversal.
3. For approximately one second following power-up of the +24V supply.

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U2c enables the polarity switching relays on the HV Power Supply Board approximately one second after the polarity control signal is switched.

There are five  $\pm 200\text{V}$  amplifiers identical to 200VPS1. These are supplied with  $\pm 270\text{V}$  rails from the converter. U13 drives an opto-coupled, single-ended, high voltage FET Q14 output stage. DC gain is set at 51 by R96 and R100 with loop compensation provided by C73 and C66. Zener D26 protects the gate of Q14 against over-voltage stress. Filter R101 C82 prevents back-coupling of RF and also limits output short circuit current. A 100:1 voltage divider is provided for the front panel test point.

The design of the 400V amplifier is nearly identical to that of the 200V amplifier except that the gain is increased to 101, the rail voltages are  $\pm 530\text{V}$  and the output voltage is shared across two FETs.

The DC-to-DC converter has an input of  $\pm 24\text{V}$  and 7 outputs:  $\pm 1100\text{V}$ ,  $\pm 530\text{V}$ ,  $+270\text{V}$  and a polarity-reversible  $1100\text{V}$  output for the fixed Curtain Plate Power Supply. The converter uses a number of clamped capacitor/peak rectifier stages to generate the various output voltages from only two secondary transformer windings. It operates partly as a flyback converter and partly as a forward converter.

The circuit is controlled by pulse-width modulation controller IC U3. The switching frequency set by C18 and R23 is  $22\text{Hz}$ . U3 regulates the  $+1100\text{V}$  output voltage by adjusting the duty cycle of switching transistor Q3 that varies between 20% and 40% depending on the load. The switch current is sensed by R6 and R7 and is filtered by R13 and C2. U3 monitors the current and will limit the duty cycle on a pulse-by-pulse basis in the case of an overload. Loop compensation is provided by C17, C25 and R26. C10, R14 and D2 form a snubber to clamp leakage inductance spikes and protect Q3 from damage. The  $+24\text{V}$  supply is filtered by L1, C34, C20 and C21. Q2 and Q4 are used to disable U3 in response to the Power Supply Enable signal.

The Curtain Plate Power Supply includes relay K1 to switch the output supply polarity. The DC current delivered to the Curtain Plate flows through R15. The voltage developed is buffered by U4b and is used to regulate the Ion Source Power Supply in regulated mode.

### 6.5.5 High-Voltage Supply Board

The output voltages of the HV Power Supply Board are controlled by externally supplied reference voltages derived from the Ion Path DACs and Vacuum Gauge Control Board.

A digital input signal controls the polarity of the Ion Source and ETP Float Voltage Supplies. A second digital signal enables or disables the outputs. Each power supply uses a power amplifier and a step-up transformer to generate a high-voltage AC waveform. The high-voltage AC is converted to DC output by voltage multiplier modules located inside the main module.

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### ETP Float Voltage Supply

The ETP Float Voltage Supply is fixed depending on the polarity of ions being analyzed. For positive ions, the voltage is -6000V; for negative ions, the voltage is fixed at +4000V. This voltage comes from the HV Power Supply Module.

The divider network is used to provide a low voltage test point for the ETP voltage. By using 1000 M $\Omega$  (R7) and 1.1 M $\Omega$  (R6), the divider ratio is set approximately 1000:1. This ensures that the test point is adequately accurate when running diagnostics.

The noise on the signal due to the ripple on the ETP+ terminal can be reduced by adding a simple RC filter (R3//C3) in series.

When there is an ion strike, the ETP generates a current pulse that flows through the connector socket. This current pulse then flows through a 511 ohm resistor (R1) producing a negative, bell-shaped pulse. The amplitude of the pulse can vary up to 200mV depending on the ETP's condition, ETP's bias voltage setting and other normal statistical variations.

The operational amplifier U1 is a precision voltage-feedback amplifier featuring fast settling time, excellent differential gain and differential phase performance. The non-inverting gain of U1 is set to 21V/V via resistors R5 and R9. Resistor R7 and diodes D1 and D2 are used to protect U1 from potential transient conditions only.

The low frequency gain of U1 is unity to reduce the effect of DC level shifts due to AC coupling of the input signal. R15 and C5 are used for the +5V power supply filtering; whereas R12 and C4 are used for the -5V power supply filtering.

The amplified pulse is conducted to the positive input of a high-speed comparator (U2), where it is compared to a discriminator voltage applied to the negative input of the comparator. Potentiometer R2, resistors R3, R4 and capacitor C1 combine to provide a stable negative DC discriminator voltage. The discriminator voltage (threshold) is the minimum pulse strength for which the signal handling circuitry will register a ion strike.

Resistors R13, R11 and capacitor C3 are used specifically to introduce hysteresis at U2 by temporarily injecting some positive feedback each time a pulse crosses the discriminator level. This is necessary to ensure that a minimum output pulse width for the counting circuit.

The non-inverted TTL output of comparator U2 is passed to the System Controller via a driver in U5. This driver converts its TTL input to balanced pseudo ECL levels. Pseudo ECL levels are ECL levels shifted by 5V to run on a single +5V power supply.

The Test Signal function helps to verify the ion counting circuitry. The test signal is a pseudo ETP output signal that originates at the System

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Controller. When it is enabled, it transmits a pulse-like test signal to the Signal Handling Board. This signal input is received and converted to TTL levels by a receiver in U5. It is then fed to the positive input of the comparator U2 via R8 and C13. If the signal handling circuitry is functioning properly, the Applications Computer will produce scan results with an ion intensity equal to the frequency of the test signal. R17, R18 and R19 are required to approximately terminate the pseudo ECL side of U5.

#### **ETP Bias Voltage Supply**

The ETP Bias Voltage Supply creates the potential gradient. The bias voltage is applied to the end of the detector opposite the horn. It is set between 2000V - 3000V more positive than the horn voltage. Therefore, ETP+ is equal to the sum of ETP- and bias voltage. The bias detector voltages are supplied from the HV Power Supply Board. Similar to the ETP-divider network, R4 and R1 are used to provide a divider approximately 1000:1.

#### **Ion Source Power Supply**

The Ion Source Power Supply generates a variable DC output between 0 kV and 8 kV in either polarity. It operates in voltage-regulated mode with the IonSpray Inlet and current-regulated mode with corona discharge for the Heated Nebulizer option. It is nearly identical to the ETP Float Voltage Power Supply with the following exceptions:

1. JFET gain control stage has been replaced by an integrated gain control IC and U4. This allows for adjusting the output down to a voltage below 100V.
2. It can be operated in current-controller mode. In this mode, the ion source current is measured at the Curtain Plate on the Lens Power Supply Board. The current is regulated by controlling the output of the Ion Source Power Supply. U6 selects either voltage mode or current mode control of the supply.

### **6.5.6 Exciter Board**

The Exciter Board consists of two sections: digital and analog.

#### **Digital**

The principal function of the Exciter Board's digital electronics is to control various ion path parameters. The key parameters controlled are the:

- Q1 and Q3 Mass DACs (16-bit)
- Q1 and Q3 Rod Offset DACs (dual, 12-bit)
- Q1 and Q3 Resolution DACs (dual 12-bit)
- Q1 and Q3 RF Mode Setting
- Power Supply Enable

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The Exciter Board receives digital data (that is, DAC values and mode settings) from the System Controller via the Synchronous Serial Link (SSL). The SSL connects to the Exciter Board through the RS422 driver and receiver chips U31 and U23 respectively.

The Exciter Board is connected to Xilinx chip U29 and U30, as well as to 12-bit ADC U34. Both U29 and U30 are configured from a common 1736 (U28) serial configuration PROM at power-up.

U29 has essentially been configured as the local SSL controller providing a generalized assortment of capabilities. For more information, refer to the *Xilinx SSL Functional Details* document and the Xilinx Configuration schematic. Addresses transferred over the SSL are decoded within U29 and, if it is in the range of 0 to 31 inclusive, will enable the appropriate local resource to accept or respond to subsequent data transfers until the next address transfer. A local resource could be within U29 or external to it, such as U30 or ADC U34.

Data destined to the Q1 (via U19) or Q3 (via U18) Rod Offset or Resolution DACs are translated to the necessary format within U29 and then output to the preload register of the appropriate DAC. When required, Scan Timing and Control (STC) signal AMU will pulse low. This causes the contents in the preload registers to simultaneously pass to the DAC outputs.

The Q1 and Q3 RF-Only mode bits and the Power Supply Enable control bit (PS\_EN) are transferred to a 16-bit parallel output register in U29 over the SSL. Both RF-Only mode bits and a derivative of the Power Supply Enable bit (Local Power Supply Enable) are passed to the analog circuitry via buffer U33.

ADC U34 receives configuration data and returns conversion results directly over the SSL. When addressed, U34 is enabled to use the SSL via a chip select from U29. U29 also provides a constant, free-running 4 MHz clock for U34's internal use.

The Q1 (U14) and Q3 (U16) Mass DACs are driven by the Xilinx design in U30. Mass DAC values are sent to U30 directly over the SSL provided that U30 has been addressed and enabled from U29. Like the Rod Offset and Resolution DACs, when there is an STC signal "settling" transitions high via U2, the contents in the Q1 and Q3 Mass DAC preload registers within U30 are simultaneously passed to the DAC outputs. The STC Increment Q1 and Increment Q3 signals increase the relevant mass DAC by one LSB. These signals are used with ramp mode scanning only.

The QPS RF and DC output voltages can be switched on or off by a Global Power Supply signal that upon entering the Exciter, is buffered and inverted by U25 on its way to Xilinx U29 (see the Power Supply Enable Logic figure). Internal to U29, the Global Power Supply signal is Nanded with a parallel output bit 15 (Power Supply Enable) resulting in an output signal (Local Power Supply Enable).

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### Analog Portion

The Analog circuitry is powered by four IC voltage regulators. This ensures that noise from the DC Power Supply does not corrupt the sensitive QPS electronics. The output voltages are  $\pm 12\text{V}$  and  $\pm 15\text{V}$ .

The analog circuitry contains the most thermally sensitive elements and is therefore enclosed in a thermally isolated, temperature stabilized oven. The oven is heated by four power transistors that are bolted to the oven extrusions. The temperature is monitored and the output is applied to a comparator that drives the power transistors to maintain a constant temperature in the oven.

The DC signal generated by the Exciter Board is derived from the Mass, Resolution and Rod Offset DACs. The Mass and Resolution DACs produce balanced outputs from two amplifiers. The Rod Offset DAC generates a common mode signal. A relay is used in RF-only mode to turn off the mass and resolution signals.

An 816 kHz signal is generated by the crystal oscillator. The active element is a current mode amplifier (U3a). The output of U3a is fed to a limiter that DC bias current. This limits the amplitude of oscillation so that U3a operates in its linear region producing a sine wave output rather than a square wave. The output of the limiter is then applied to a resonant circuit that filters the signal and applies it to the non-inverting input of U3a providing the positive feedback required for oscillation.

The balanced detector signal is summed by the U6 instrumentation amplifier. The output signal from the Mass DAC is applied to the inverting input of an operational amplifier (U12a); the non-inverting input is grounded. The RF level then adjusts itself so that the output of U6 applied to U12a cancels the Mass DAC signal. U12a is wired as an integrator that forces the static error of the RF feedback to zero. U12b inverts the polarity of the control signal from U12a and reduces its amplitude to the 0 to 2V range required for U5 (the multiplier stage). The circuitry for the other rod set is identical.

### 6.5.7 Amplifier Boards

The Amplifier Boards condition and amplify the RF and DC signals received from the Exciter Board and pass them on to the coil boxes. There are two identical Amplifier Boards: one for Q1 and the other for Q3. Each contain an RF stage and a DC stage.

The RF amplifier output stage consists of four amplifiers arranged as a parallel push/pull circuit. The amplifiers are powered by two IC voltage regulators. The maximum output RF voltage is 30V peak-to-peak.

The DC output stage consists of two DC amplifiers that use 6 series-connected FETs to obtain the required output voltage capability. The gain of the DC amplifiers is controlled by a precision voltage divider with a low

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temperature coefficient. The circuitry of the two DC amplifiers differs slightly. One has a +200V offset capability and the other has a -200V offset capability. The amplifiers have an output swing of over 800V. The outputs are short-circuit protected.

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## 6.6 Temperature Controller

### 6.6.1 Temperature Control System

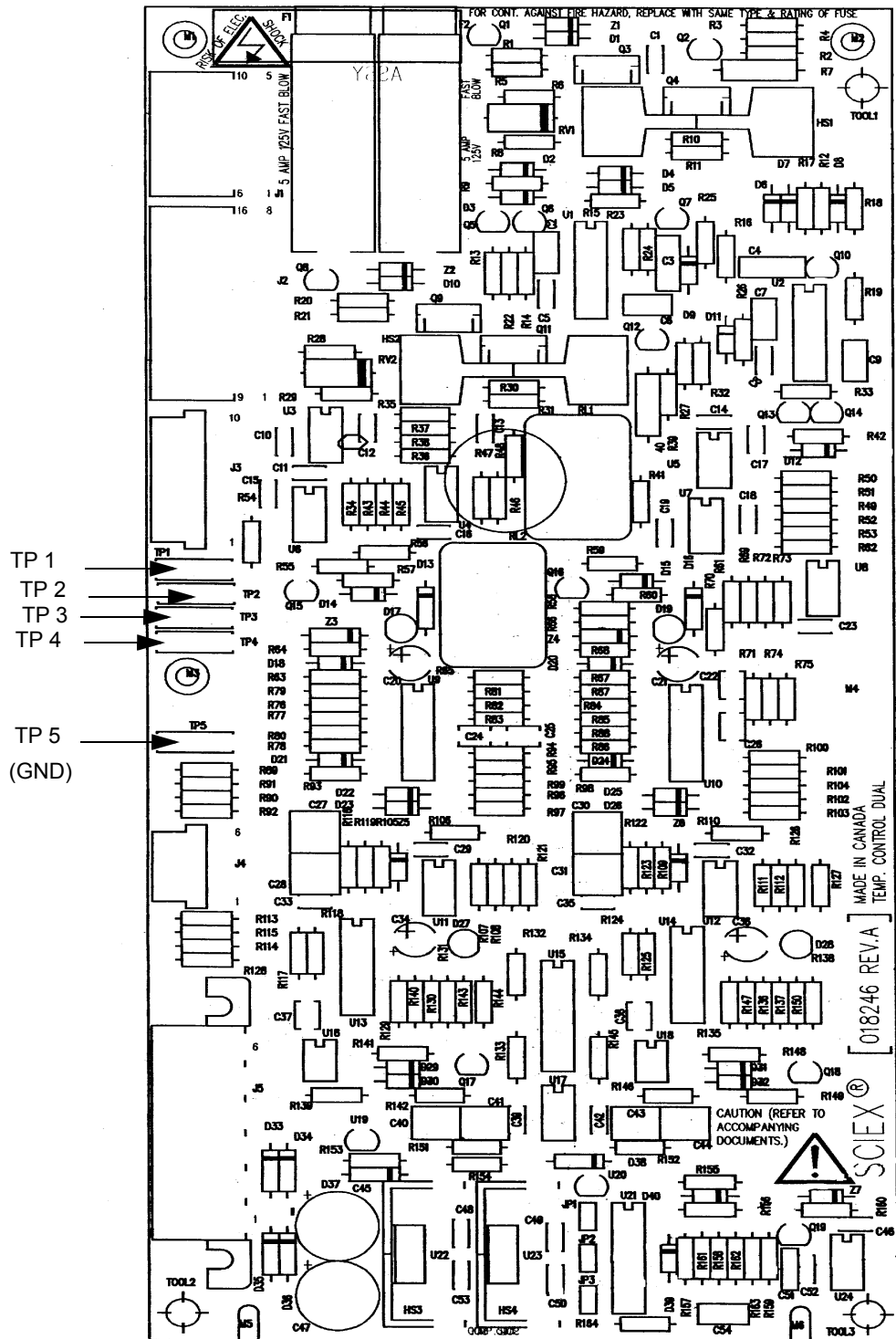
The temperature control system provides for the control of the heating of the interface assembly and the TurbolonSpray or Heated Nebulizer inlets where these are used. This requires two temperature controllers which are mounted on one printed circuit assembly. The power for this system is provided by a single mains transformer. This transformer provides 60 VAC to the heaters and a 32 VAC center tapped winding used to generate power for the control circuits.

The interface is heated to a temperature of about 100 DC by a Kaptan film heater element rated at 200W when energized with 60 VAC. The temperature of the interface is monitored by a Platinum Resistance Temperature Detector (RTD) with a resistance of 100 Ohms at 0°C. The temperature controller receives a nonadjustable set point command from the DACS and Vacuum Gauge module.

The Heated Nebulizer or TurbolonSpray inlets are heated to a temperature of about 500°C by a mineral filled heater element rated at 200W when energized with 60 VAC. The temperature of the heater is monitored by a Platinum Resistance Temperature Detector (RTD) with a resistance of 100 Ohms at 0°C. The temperature controller receives a set point command from a Digital to Analog Converter under computer control.

The following Test Points are located on the Temperature Controller board:

- TP 1 Set value - Interface, Typically 1 volt
- TP 2 Read back value - Interface, Typically 1 volt
- TP 3 Set value for source heater (10 mV per degree)
- TP 4 Read back value for source heater (10 mV per degree)
- TP 5 Ground (GND)



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## 6.7 Q1 and Q3 Coil Box

The Q1 and Q3 Coil Boxes are mounted against the pillars underneath the Vacuum Chamber in line with the Q1 and Q3 Mass Filters. The Boxes house the filter board assemblies that amplify the QPS voltages. The voltages are relayed to the respective Q1 and Q3 quadrupoles by vacuum feedthrough leads through the top of the respective coil box. The applied RF Voltages are measured for a feedback loop by the RF Detector Boxes that connect through the back of the pillar into the rear of the coil boxes.

The two coil box assemblies are similar. All parts that make up the Assemblies are the same except for the wireforms that link the resonating coil output to the respective RF Detector, tuning capacitor and RF Feedthroughs. The Q1 and Q3 wireforms have different shapes that reflect the different coil box orientations.

The procedure to replace the coil box, the filter board assemblies, or the Tuning capacitors are the same for both coil boxes. The following procedure can be used to repair or replace either coil box. Specific instructions are provided where necessary to note the minor differences in the Q1 and Q3 Coil Boxes.




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**WARNING**     **BIOHAZARDOUS MATERIAL** *Do not dispose of system components or subassemblies, including computer parts, in municipal waste. Dispose of replaced components and instruments according to established waste electrical equipment procedures.*

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---

**WARNING**     **Be careful of the high voltage.** *Ensure that the instrument is shut off and that the main power line is disconnected before opening the Coil Boxes.*

---



---

**Note**     *This procedure is designed assuming the rear of the pillar is accessible. In some cases, you may have to remove the source exhaust pump housing to access to the Q1 pillar.*

---

### Removing the Filter Board Assembly

1. Shut down the instrument.
2. Open the Source Cover.
3. Open the Front Cover.
4. Remove the Back Cover.

5. Remove the Coil Box Cover.
6. Separate the wireforms and the resonating coil output (LITZ) wires from the tuning capacitors. The Q1 Filter Board Assembly Connections figure shows the connections for Q1 Coil Box. The Q3 Feedthrough Installation Schematic figure shows the connections for the Q3 Coil Box.

---

**Note**      *The coil wire is wrapped several times around the wireform lead or capacitor wire and soldered. Disconnect the coil wire careful so that it does not break.*

---



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**Note**      *Use a 60 watt soldering iron to burn off the coating on the coil wire (LITZ). Use a good rosin core solder to make a good connection.*

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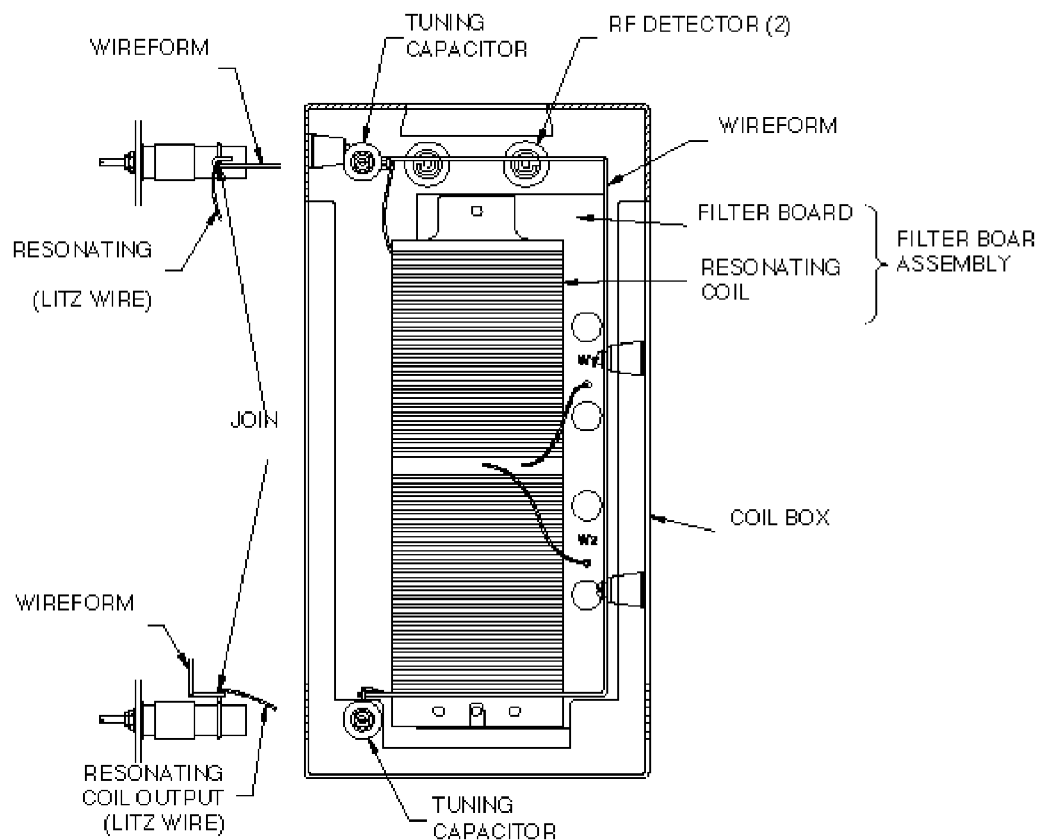


**Figure 6-10. Q1 Filter Board Assembly Connections**

7. Unlatch the feedthrough latch mechanism secures the feedthrough locking mechanism to the feedthrough housing. Slide out the silver

---

plate. See Coil Box Connections - Rear and Side View figure.

---

**Caution**      *The vacuum feedthroughs are sensitive to contamination. Always wear powder-free latex gloves when handling the feedthroughs and place them in a plastic bag immediately after removal to ensure they remain clean.*

---

8. Hold the ceramic collar of the front feedthrough and slide the wireform sleeve connector off the bottom end of the feedthrough.

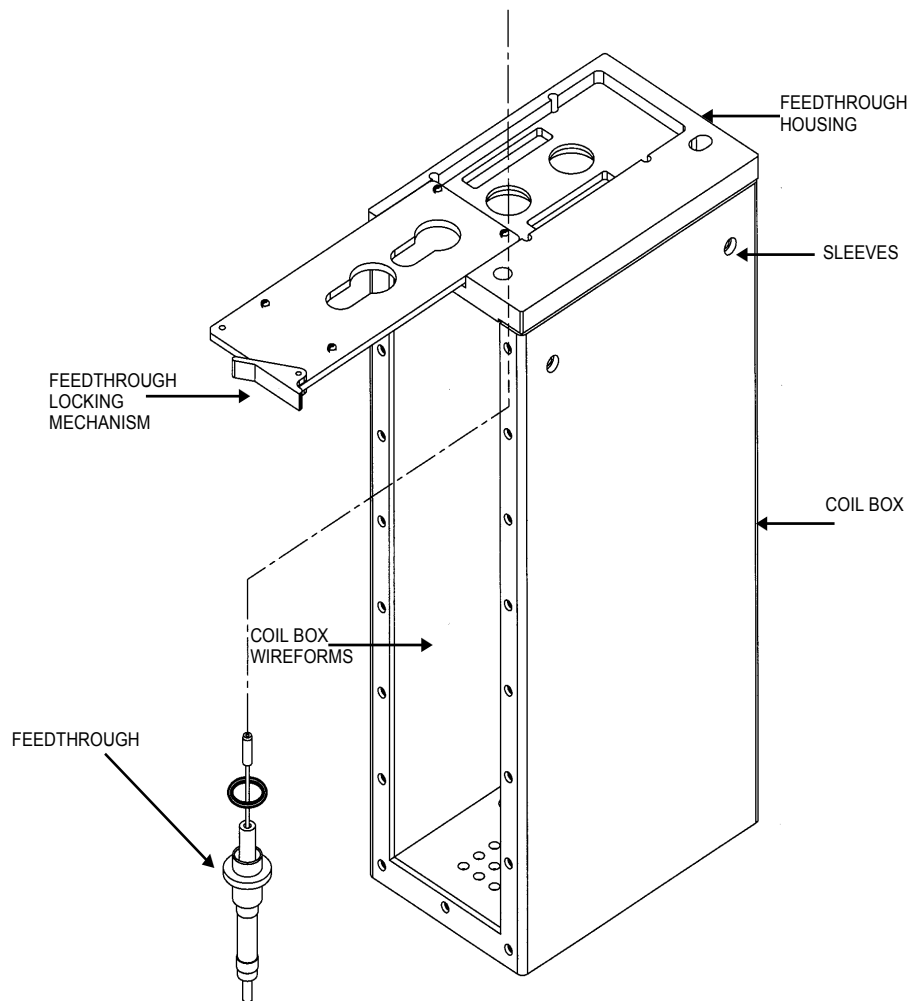


Figure 6-11. Q3 Feedthrough Installation Schematic

9. Gently pull the feedthrough straight out of the Vacuum Chamber and maneuver it out of the coil box.

10. Repeat steps 7-9 for the second feedthrough that is directly behind the first.
11. From the back of the instrument, disconnect the four cables that connect to the filter board through the pillar. The next figure shows the cable connections for the Q1 and Q3 Assemblies.

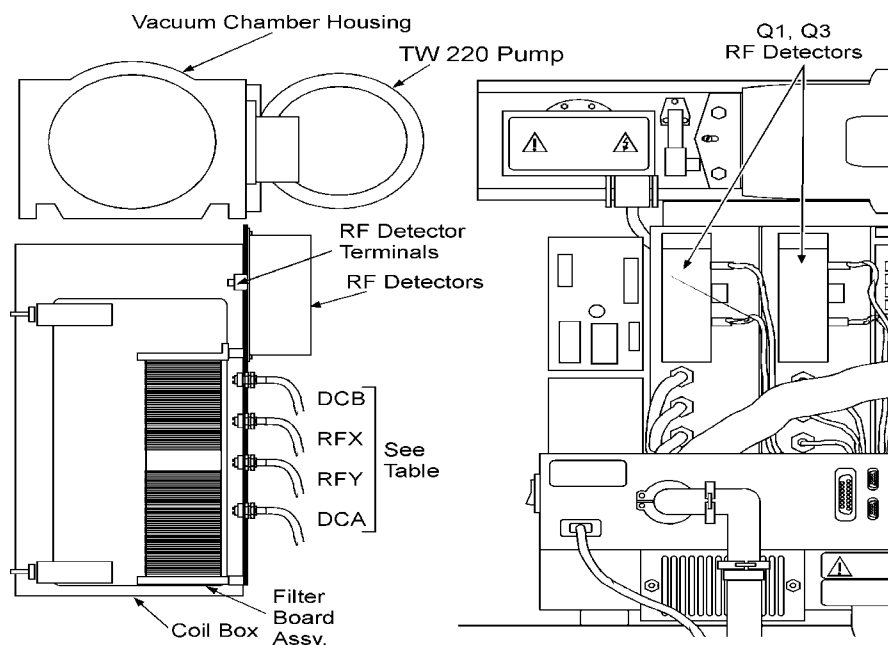


**Figure 6-12. Coil Box Connections - Rear and Side View**

12. With a 9/16 socket, remove the four hexagonal jam nuts and lock the washers that secure the filter board connectors to the pillar.
13. From the back of the instrument unscrew the four hex-head screws that thread into the standoffs on the filter board through the pillar.

**Table 6-5. Coil Box Connections**

|    |             |        | MB Connector |
|----|-------------|--------|--------------|
| Q1 | Coil Box    | DC1B   | J15          |
|    |             | RF1X   | J17          |
|    |             | RF1Y   | J18          |
|    |             | DC1A   | J16          |
|    | RF Detector | FB1B   | J30          |
|    |             | FB1A   | J29          |
|    |             | Heater | J43          |

|    |             |                              |                          |
|----|-------------|------------------------------|--------------------------|
| Q3 | Coil Box    | DC3B<br>RF3X<br>RF3Y<br>DC3A | J19<br>J21<br>J22<br>J20 |
|    | RF Detector | FB3B<br>FB3A<br>Heater       | J32<br>J31<br>J42        |

14. From the front of the machine, maneuver the filter board assembly clear of the coil box.

---

**Caution**      ***Do not displace the coil wrappings. The coil spacing is critical to the coil box performance. The coil wraps are held in position with a strip of silicon gel down the side of the coil. Be careful not to damage the silicon.***

---

#### Replacing the Filter Board Assembly

1. Maneuver the filter board assembly into the coil box so that the four connectors on the filter board fit through the pillar.
2. From the back of the instrument, place the 1/2" lock washers over the filter board connectors and hand tighten the 1/2" jam nuts to the connectors.
3. From the back of the instrument, screw the four hex-head screws with flat washers through the pillar into the standoffs on the filter board assembly.
4. Tighten the four jam nuts (from step 3) to the connectors.
5. Wrap the resonating coil output (LITZ) wire several times around the wireform at the top tuning capacitor leaving a minimum of slack. See the Q1 Filter Board Assembly Connections figure for Q1 and the Q3 Feedthrough Installation Schematic figure for Q3.

---

**Caution**      ***The LITZ wire from the coil should never be closer to the sides of the coil box than the wireform leads. Do not leave any sharp edges in the coil box connections or arcing may occur.***

---

6. Solder the resonating coil output (LITZ) wire to the wireform. Trim the excess wire and reflow the solder.
7. Wrap the resonating coil output (LITZ) wire several times around the wireform at the join with the bottom tuning capacitor leaving a minimum of slack. See the Q1 Filter Board Assembly Connections figure for Q1 and the Q3 Feedthrough Installation Schematic figure for

---

Q3.

8. Solder the resonating coil output (LITZ) wire to the wireform. Trim the excess wire and reflow the solder.
9. With a multimeter, measure the resistance between the following points. Each resistance should be less than 1.5 ohms:

---

|             |                                                                                                 |
|-------------|-------------------------------------------------------------------------------------------------|
| <b>Note</b> | <i>The 1.5 ohm resistance value is the value after the lead resistance has been subtracted.</i> |
|-------------|-------------------------------------------------------------------------------------------------|

---

- W1 on the filter board and the top wireform — LITZ wire connection
  - W1 and the body of the top tuning capacitor
  - W2 on the filter board and the bottom wireform — LITZ wire connection
  - W2 and the body of the lower tuning capacitor
10. Before closing the coil boxes, check the following:
    - That the wireform sleeve connectors are seated securely over the two RF detector connectors at the back of the coil box
    - That the wireform sleeve connectors are seated securely over both vacuum feedthrough connectors
    - That the soldered connections joining the tuning capacitors to the wireforms is secure and that the lead from the capacitors is not broken
    - That the fly leads from the top and bottom of each coil are soldered securely to the wireforms. Each of the fly leads must not be closer to the walls of the coil box than the wireforms

---

|                |                                                                                                    |
|----------------|----------------------------------------------------------------------------------------------------|
| <b>Caution</b> | <b><i>Failure to connect the coil boxes properly may result in damage to the RF detectors.</i></b> |
|----------------|----------------------------------------------------------------------------------------------------|

---

11. Replace the Q1 and Q3 Coil Box covers and tighten the 12 hex-head screws with the associated washers.

#### Removing and Replacing the Tuning Capacitors

Each of the coil boxes has two tuning capacitors. The following procedure can be followed to change any or all of the capacitors. The only differences in the tuning capacitors result from the different orientations inside the coil boxes. The differences are shown in the Q1 Filter Board Assembly Connections figure and the Q3 Feedthrough Installation Schematic figure.

1. Shut down the instrument.
2. Open the Source Cover.

- 
3. Open the Front Cover.
  4. Remove the Back Cover.
  5. Remove the Coil Box Cover.
  6. Separate the wireforms and the resonating coil output (LITZ) wires from the tuning capacitors. The Q1 Filter Board Assembly Connections figure shows the connections for Q1 Coil Box. The Q3 Feedthrough Installation Schematic figure shows the connections for the Q3 Coil Box.

---

|             |                                                                                                                                                                      |
|-------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Note</b> | <i>The coil wire is wrapped several times around the wireform lead or capacitor wire and soldered. Carefully disconnect the coil wire so that it does not break.</i> |
|-------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|

---

7. Unscrew the nut at the front of the coil box that secures the tuning capacitor to the coil box.
8. Reach inside the coil box and maneuver the tuning capacitor through the Coil Box cover and out of the coil box.
9. Position the new capacitor in the coil box and, from the front, tighten the nut over the adjustable arm of the capacitor.
10. Solder the wireform to the wire lead wrapped around the capacitor. See the Q1 Filter Board Assembly Connections figure and the Q3 Feedthrough Installation Schematic figure.
11. Wrap the resonating coil output (LITZ) wire several times around the wireform at the tuning capacitor leaving a minimum of slack. See the Q1 Filter Board Assembly Connections figure for Q1 and the Q3 Feedthrough Installation Schematic figure for Q3.

---

|                |                                                                                                                        |
|----------------|------------------------------------------------------------------------------------------------------------------------|
| <b>Caution</b> | <b><i>The LITZ wire from the coil should never be closer to the sides of the coil box than the wireform leads.</i></b> |
|----------------|------------------------------------------------------------------------------------------------------------------------|

---

12. Solder the resonating coil output (LITZ) wire to the wireform, then trim the excess wire and reflow the solder.
13. With a multimeter, measure the resistance between the following points, each of which should be less than 1.5 ohms:

---

|             |                                                                                                 |
|-------------|-------------------------------------------------------------------------------------------------|
| <b>Note</b> | <i>The 1.5 ohm resistance value is the value after the lead resistance has been subtracted.</i> |
|-------------|-------------------------------------------------------------------------------------------------|

---

- W1 on the filter board and the top wireform — LITZ wire connection

- 
- W1 and the body of the top tuning capacitor
  - W2 on the filter board and the bottom wireform — LITZ wire connection
  - W2 and the body of the lower tuning capacitor

14. Before closing the coil boxes, check the following:

- That the wireform sleeve connectors are seated securely over the two RF detector connectors at the back of the coil box
- That the wireform sleeve connectors are seated securely over both vacuum feedthrough connectors
- That the soldered connections joining the tuning capacitors to the wireforms is secure and that the leads from the capacitors are not broken
- That the fly leads from the top and bottom of each coil are soldered securely to the wireforms. Each of the fly leads must not be closer to the walls of the coil box than the wireforms

---

|                |                                                                                                    |
|----------------|----------------------------------------------------------------------------------------------------|
| <b>Caution</b> | <b><i>Failure to connect the coil boxes properly may result in damage to the RF detectors.</i></b> |
|----------------|----------------------------------------------------------------------------------------------------|

---

15. Replace the coil box cover and tighten the 12 hex-head screws with the associated washers.

Removing the RF Detector Boxes

1. Shut down the instrument.
2. Open the Source Cover.
3. Open the Front Cover.
4. Remove the Back Cover.
5. Remove the Coil Box Cover.
6. Slide the wireform collars from both vacuum feedthroughs in the coil box.
7. Slide the wireform collars off the RF Detector terminals at the inside back of the coil box.
8. Disconnect the two RF Feedback connections from the back of the RF Detector Box.
9. Disconnect the 6-pin connector attached to the Heater Board below the RF Detector Box.
10. From the front of the instrument, while reaching over the instrument and holding the Detector Box, unscrew and remove the two screws securing the RF Detector to the pillar.

- 
11. Lift the RF Detector from the pillar.
  12. Insert the replacement RF Detector Box through the back of the pillar into the coil box. From inside the coil box, thread two hex-head screws with flat washers into the RF Detector Boxes through the pillar.
  13. Fit the wireform collar over the RF Detector terminals, as shown for the respective coil boxes in the Q1 Filter Board Assembly Connections figure for Q1 and the Q3 Feedthrough Installation Schematic figure.
  14. Fit the wireform collar leads over the vacuum feedthroughs. See the Q1 Filter Board Assembly Connections figure for Q1 or the Q3 Feedthrough Installation Schematic figure for Q3.
  15. With a multimeter, measure the resistance between the following points. Each resistance should be less than 1.5 ohms:

---

|             |                                                                                                 |
|-------------|-------------------------------------------------------------------------------------------------|
| <b>Note</b> | <i>The 1.5 ohm resistance value is the value after the lead resistance has been subtracted.</i> |
|-------------|-------------------------------------------------------------------------------------------------|

---

- W1 on the filter board and the top wireform — LITZ wire connection
  - W1 and the body of the top tuning capacitor
  - W2 on the filter board and the bottom wireform — LITZ wire connection
  - W2 and the body of the lower tuning capacitor
16. Before closing the coil boxes, check the following:
    - That the wireform sleeve connectors are seated securely over the two RF detector connectors at the back of the coil box
    - That the wireform sleeve connectors are seated securely over both vacuum feedthrough connectors
    - That the soldered connections joining the tuning capacitors to the wireforms is secure and that the leads from the capacitors are not broken
    - That the fly leads from the top and bottom of each coil are soldered securely to the wireforms. Each of the fly leads must not be closer to the walls of the coil box than the wireforms

---

|                |                                                                                                    |
|----------------|----------------------------------------------------------------------------------------------------|
| <b>Caution</b> | <b><i>Failure to connect the coil boxes properly may result in damage to the RF detectors.</i></b> |
|----------------|----------------------------------------------------------------------------------------------------|

---

17. Replace the coil box cover and tighten the 12 hex-head screws with the associated washers.

---

## Removing the Coil Box

The coil box itself can be removed without removing the filter board assembly because there is no complete back wall to the coil box. The pillar forms the back of the box when the coil box is secured in position.

To remove the coil box itself, you must remove the RF Detector and disconnect the vacuum feedthroughs and tuning capacitors. You can then remove the coil box with the wireforms attached to the standoffs.



---

**WARNING**     **BIOHAZARDOUS MATERIAL** *Do not dispose of system components or subassemblies, including computer parts, in municipal waste. Dispose of replaced components and instruments according to established waste electrical equipment procedures.*

---

---

*Note*                *This procedure is designed assuming the back side of the pillar is accessible. You may have to remove the source exhaust pump housing or the transformer housing to access to the Q1 pillar.*

---

1. Shut down the instrument.
2. Open the Source Cover.
3. Open the Front Cover.
4. Remove the Back Cover.
5. Remove the Coil Box Cover.
6. Unclip the clamp that secures the feedthrough locking mechanism to the feedthrough housing.

---

**Caution**        *The vacuum feedthroughs are sensitive to contamination. Always wear powder-free latex gloves when handling the feedthroughs and place them in a plastic bag immediately after removal to ensure they remain clean.*

---

7. Remove the 18 screws from the coil box plate.
8. To remove the feedthroughs, unscrew the bolts on the top of the coil box.
9. Disconnect the RF Connectors.
10. Remove the Filter Board Assembly.
11. Remove the two M-5 hex bolts on the bottom of the coil box.

- 
12. Remove the coil box.
  13. With a multimeter, measure the resistance between the following points. Each resistance should be less than 1.5 ohms:

---

|             |                                                                                                 |
|-------------|-------------------------------------------------------------------------------------------------|
| <b>Note</b> | <i>The 1.5 ohm resistance value is the value after the lead resistance has been subtracted.</i> |
|-------------|-------------------------------------------------------------------------------------------------|

---

- W1 on the filter board and the top wireform — LITZ wire connection
  - One and the body of the top tuning capacitor
  - Two on the filter board and the bottom wireform — LITZ wire connection
  - W2 and the body of the lower tuning capacitor
14. Before closing the coil box, check the following:
    - That the wireform sleeve connectors are seated securely over the two RF detector connectors at the back of the coil box
    - That the wireform sleeve connectors are seated securely over both vacuum feedthrough connectors
    - That the soldered connections joining the tuning capacitors to the wireforms is secure and that the leads from the capacitors are not broken
    - That the fly leads from the top and bottom of each coil are soldered securely to the wireforms. Each of the fly leads must not be closer to the walls of the coil box than the wireforms

---

|                |                                                                                     |
|----------------|-------------------------------------------------------------------------------------|
| <b>Caution</b> | <b><i>Failure to connect the coil box properly can damage the RF detectors.</i></b> |
|----------------|-------------------------------------------------------------------------------------|

---

15. Replace the coil box cover and tighten the 18 hex-head screws.

---

## 6.7 Card Cage Blower

The Card Cage fan is installed under the circuit board modules as part of the System Electronics Box Assembly. The fan circulates air through the circuit board modules and through both the Q1 and Q3 Coil Boxes. Vents in the coil box assemblies allow the air from the fan to pass over the coils and out the front vents in the Coil Box cover.

The fan is connected in parallel to the AC Distribution Board that supplies them with 230 volts AC power. The fan operates continually when the main circuit breaker switch is "ON".

### Replacing the Card Cage Blower

1. Shut down the instrument.
2. Open the Front Cover.
3. Remove all the System boards from the Card Cage.
4. Remove the Filter covers.
5. Using a screwdriver, remove the four Phillips screws holding the fan assembly in place.
6. Pull out the Card Cage Blower.
7. To replace the fan, reverse steps 4 to 6.

### Assembling the Card Cage

1. Using four screws and lock washers, secure the four bars to the right-hand card cage end plate. Do not tighten the screws.
2. Using one screw and lock washer, fasten the bar to the end plate, noting the orientation. Do not tighten the screw.
3. Slide the bar into each of the four corner bars.
4. Using the four screws and lock washers, fasten the left-hand card cage end plate to the ends of the bars.
5. Using the screw and washer, install the vacuum hose support. Do not tighten the screw.
6. Using 20 screws, secure the terminal and the seven cable tie clamps. Loosely fasten the motherboard assembly to the card cage bars. Observe the orientation of the motherboard.
7. Place the card cage on a flat surface and fully tighten the motherboard screws.
8. While the card cage assembly is still on the flat surface, fully tighten the 10 screws holding the end plates to the bars.

- 
9. Using the screws, lock washers and flat washers, install the front cover mount bracket to the Vacuum Chamber support.
  10. Using the four cap screws and lock washers, fasten the completed Vacuum Chamber bracket to the top of the card cage. Fully tighten the screws.
  11. Install the quarter-turn screw clips to the support bracket.
  12. Using the clamp and screw, mount the temperature sensor to the vacuum hose support bracket.
  13. Install the 14 card guides.

#### Assembling the Fan Assembly

1. Prepare the electrical cable on the fan by trimming the jacket and conductors to the appropriate length. Strip the insulation from the conductors to the appropriate strip length.
2. Solder the fan power connector to the connectors.
3. Using the four flat-head screws, attach the fan to the fan plate. The electrical conductors should exit the fan toward the connector hole in the fan housing plate.
4. Using the washer and nut provided, install the fan power connector in the insulating bracket.
5. Dress the fan conductors so that they are held against the fan plate by using the insulating bracket. Using the two screws, fasten the insulating bracket to the fan plate.
6. Using the four screws, fasten the fan plate to the fan housing. Ensure that the fan spins freely without interference with the fan housing or connection wires.

---

## 6.8 Power Distribution Module Service

The Power Distribution module consists of the AC Distribution Board and the DC Power Supply. The AC Distribution Board can not be removed with the DC Power Supply mounted. To remove the DC Power Supply, the AC bracket must be disconnected to expose four screws that attach the DC Power Supply to the back of the AC bracket.



---

**WARNING**     **BIOHAZARDOUS MATERIAL** *Do not dispose of system components or subassemblies, including computer parts, in municipal waste. Dispose of replaced components and instruments according to established waste electrical equipment procedures.*

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Procedures to remove the Power Distribution Module components must be performed in the following order:

- Remove the Power Distribution Module cover.
- Disconnect the AC bracket.
- Remove the DC Power Supply.
- Remove the AC Distribution Board.

Removing the DC Power Supply

1. Shut down the instrument.
2. Remove the Back Cover.
3. Open the Front Cover.



---

**WARNING**     *Do not touch the DC power supply until five minutes after switching off the main switch. The delay allows the capacitors in the DC power source to safely discharge.*

---

4. Disconnect all electrical connections to the AC Power Supply and all other cable connections.
5. Disconnect the AC Power Supply at the other end of the AC Distribution Box.
6. Remove the two bolts that secure the AC Distribution Box to the back panel.
7. If the handles are attached to the chassis, remove the handle from the detector end of the chassis.

---

*Note*                      *To open the power module cover, you must remove the handle.*

---

8. Slide the bottom of the Power Distribution Module Cover off the edge of the chassis and lay the cover down close to the instrument.
9. With a 3 mm Allen key, remove the two hex-head screws that connect the two bottom front corners of the AC bracket to the Chassis.
10. Carefully cut the cable tie that secures the following cables to the Chassis between the line filter and the AC bracket:
  - AC Main Input cable
  - AC Power Input for DC Power Supply
  - 230 VAC input to the AC Distribution Board cable ACJ2
11. Unscrew and remove the two hex-head screws that secure the top of the AC bracket to the Q3 Vacuum Feedthrough Housing. See the figure below.
12. Disconnect the ion optics cable.

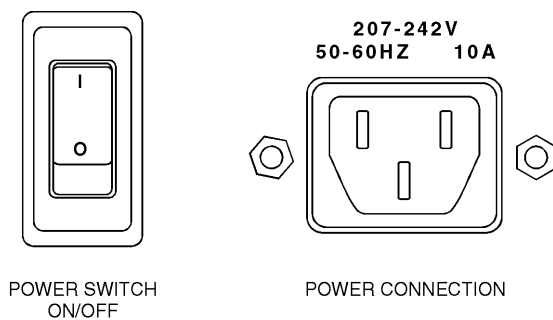


**Figure 6-13. Power Connectors Layout**

13. Turn the Power Distribution Module counter-clockwise so the rear of the AC bracket is accessible from the front of the instrument.

---

*Note*                      *The Power Distribution Module remains connected to the main console by cabling, but it is maneuverable enough to expose the DC Power Supply mounting screws at the back of the AC bracket.*

---

14. Disconnect the 12 DC Power Input Cable leads from the top of the DC Power Supply.

15. Remove the eight Philips head screws that fasten the DC Power Supply to the AC bracket.
16. Remove the DC Power Supply from the AC bracket. Guide the AC Power Input Cable connected to the bottom of the Power Supply through the opening in the AC bracket below the AC Distribution Board.

#### Removing and Replacing the AC Distribution Board



**WARNING**     **BIOHAZARDOUS MATERIAL** *Do not dispose of system components or subassemblies, including computer parts, in municipal waste. Dispose of replaced components and instruments according to established waste electrical equipment procedures.*

1. Shut down the instrument.

**Caution**     **Remove power cord from the instrument for safety**

2. Remove the DC Power Supply.
3. Disconnect all the connections to the AC Distribution Board.
4. Using a 2.5 mm Allen key, remove the screws securing the AC Distribution Board to the AC bracket standoffs and remove the AC Distribution Board.
5. Turn each of the four Fuse Caps on the replacement AC Distribution Board counter-clockwise 1/4 turn to release the caps. Verify that the proper fuses are inserted in the fuse caps as listed below.

**Table 6-6. Power Distribution Board - Fuse Distribution**

|        |                |                      |
|--------|----------------|----------------------|
| Fuse 1 | Turbo Cooling  | 2.5A -250V Time-lag  |
| Fuse 2 | Divertor Valve | 4.0A - 250V Time-lag |

**Caution**     **When replacing fuses, always use the correct replacement type and amperage**

6. Position the AC Distribution Board so that the connectors line up with the slots in the AC bracket and tighten the four screws that attach the AC Distribution Board to the AC bracket standoffs.
7. Replace the DC Power Supply. See the next procedure.5

#### Replacing DC Power Supply

1. Attach the AC Input Cable to the replacement DC Power Supply as shown in the DC Power Supply Connections figure.
2. Feed the AC Input Cable through the cable opening in the AC bracket below the AC Distribution Board while maneuvering the replacement DC Power Supply into position inside the AC bracket.
3. Remove and discard the six straps across the replacement DC Power Supply output terminals.

---

**Note**      *Removing these straps enables the sensing circuit. If the straps are not removed, the sensing circuit will monitor the voltage drop across the DC Power Supply output terminals not across the load on the motherboard.*

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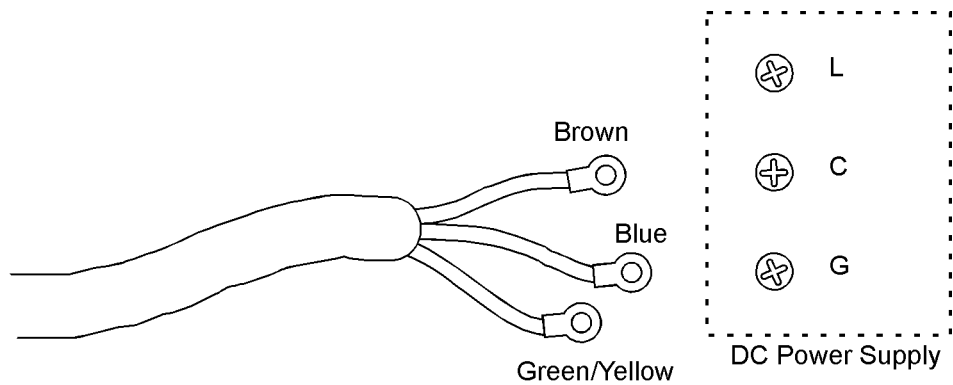


**Figure 6-14. DC Power Supply AC Input Connection**

4. Align the threaded mounting holes on the back and left sides of the Power Supply with the corresponding holes in the Bracket and screw the four Philips screws through the AC bracket into the Power Supply. See the figure above.
5. Attach the DC Input Cable to the 12 DC output connectors as shown in the Main Switch Connections figure.

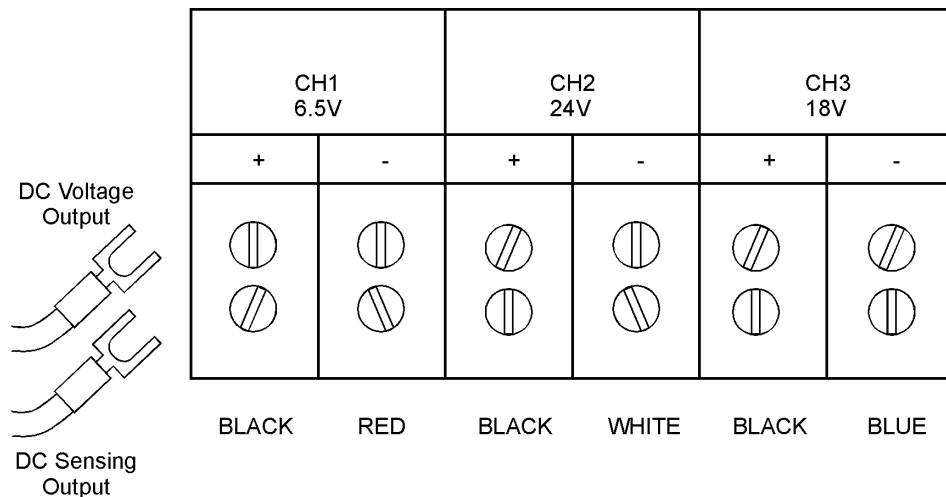


**Figure 6-15. DC Power Supply Connections**

6. Slide the module into position and thread the two screws with lock washers and flat washers through the bottom front corners of the AC bracket assembly to the chassis. See the DC Power Supply AC Input figure.
7. Replace and tighten the two screws that secure the top of the assembly to the Q3 RF Feedthrough Housing. See the DC Power Supply AC Input Connection figure.
8. Fit a cable tie through the clamp on the chassis between the line filter and the AC bracket and tighten it around the following cables:
  - the AC Main Input cable from the AC line filter
  - the 230 VAC input cable to the AC Distribution Board
  - the AC Input cable to the DC Power Supply
9. Re-connect the AC output cables to the appropriate connector on the AC Distribution board.
10. Replace the Power Distribution Module Cover and tighten the four hex-head screws that secure it in position. Ensure that the flat washer and the lock washer are in place. See the Power Distribution Module Assembly figure.
11. Connect the ETP Cable to the Signal Handling Board.
12. Connect the Ion Optics Power Cable to the Vacuum Chamber rear flange.

---

## 6.9 Main Circuit Breaker Switch

The Main Circuit Breaker Switch on the Power Distribution Module Cover controls the flow of power from the 230 VAC supply to the Power Distribution Module. When the Switch is “ON”, the power is directed via the AC Distribution input cable to the AC Distribution Board.

The Switch also acts as a circuit breaker to protect the instrument from power surges. If the voltage (current) in the input line exceeds 12 A, the circuit breaker trips disabling power to the AC Distribution Board.




---

**WARNING**      **BIOHAZARDOUS MATERIAL** *Do not dispose of system components or subassemblies, including computer parts, in municipal waste. Dispose of replaced components and instruments according to established waste electrical equipment procedures.*

---

### Removing the Switch

1. Shut down the instrument.

---

**Caution**      **Remove power cord from the instrument for safety**

---

2. Open the Source Cover.
3. Remove the Back Cover.
4. Open the Front Cover.
5. Remove the four hex-head screws that connect through the AC bracket to the side corners of the Power Distribution Module Cover. See the Power Distribution Module Assembly figure.
6. Carefully slide the bottom of the Power Distribution Module Cover off the chassis and lay it down in front of the assembly.

---

**Caution**      **The Power Distribution Module Cover cannot be moved from the instrument because the Switch and the Reset buttons on the Cover are wired to the main console.**

---

7. Disconnect the four leads from the switch.
8. To remove the switch, squeeze the spring catches and push the switch through the front of the Power Distribution Module Cover. See the Coil

### Box Connections - Rear and Side View figure.

#### Replacing the Switch

1. Push the replacement switch through the front of the Power Distribution Module Cover until it snaps into position.
2. Connect the leads from AC Distribution Input Cable and the AC Main Circuit Breaker Cable to the connectors on the switch as shown in the next figure.
3. Replace the Power Distribution Module Cover.

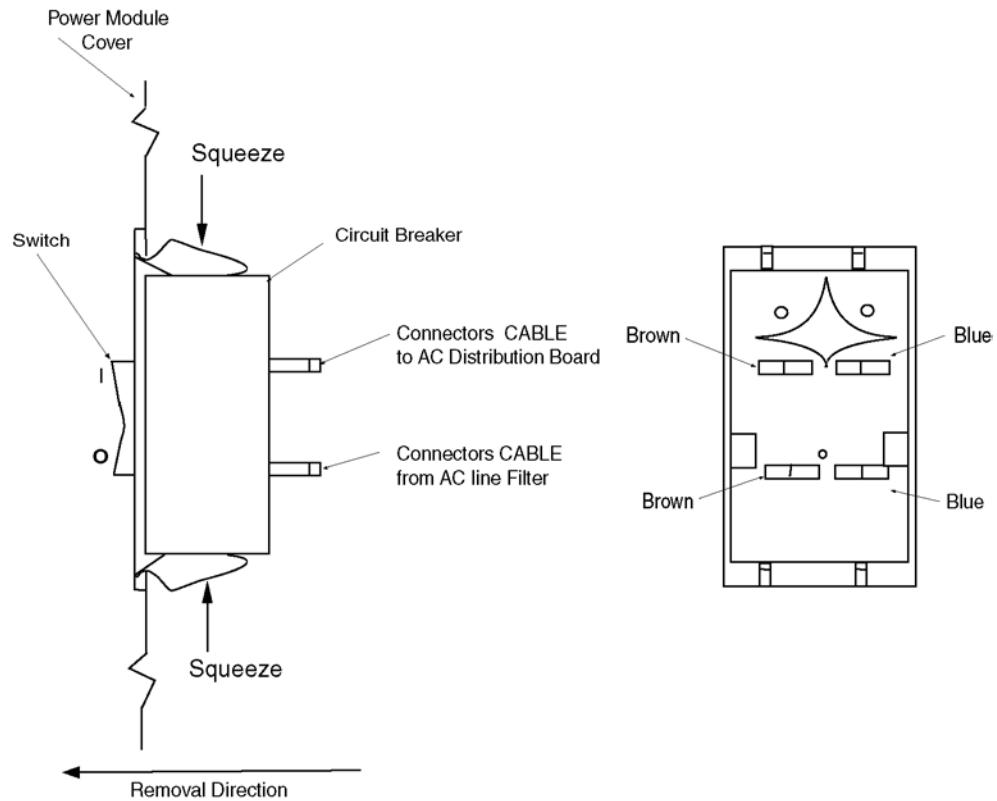


**Figure 6-16. Main Switch Connections**